National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Long-term Coho Salmon and Steelhead Trout Monitoring in Coastal Marin County

2007 Annual Monitoring Report

Natural Resource Technical Report NPS/SFAN/NRTR—2009/269

ON THE COVER
Adult coho salmon on John West Fork - Olema Creek
Photograph by: Greg Brown
Juvenile coho salmon on Olema Creek
Photo by: Sarah Carlisle
Smolt coho salmon on Redwood Creek
Photograph by: Casey Del Real

Long-term Coho Salmon and Steelhead Trout Monitoring in Coastal Marin County

2007 Annual Monitoring Report

Natural Resource Technical Report NPS/SFAN/NRTR—2009/269

Sarah Carlisle[1]
Michael Reichmuth[2]
Erin Brown[3]
Casey del Real[1]

[1]Point Reyes National Seashore Association, Coho and Steelhead Restoration Project
1 Bear Valley Road
Point Reyes Station, Ca 94956

[2]National Park Service, San Francisco Bay Area Network Inventory and Monitoring Program,
Point Reyes National Seashore
1 Bear Valley Road
Point Reyes Station, Ca 94956

[3]Conservation Corps North Bay
1 Bear Valley Road
Point Reyes Station, Ca 94956

November 2009

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

The National Park Service, Natural Resource Program Center publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Technical Report Series is used to disseminate results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service mission. The series provides contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

Views, statements, findings, conclusions, recommendations, and data in this report are those of the author(s) and do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the National Park Service.

This report is available from San Francisco Bay Area I&M Network website (http://www.nature.nps.gov/im/units/SFAN) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/NRPM).

Please cite this publication as:

Carlisle, S., M. Reichmuth, E. Brown, and S. C. Del Real. 2008. Long-term coho salmon and steelhead trout monitoring in coastal Marin County 2007: annual monitoring progress report. Natural Resource Technical Report NPS/SFAN/NRTR—2009/269. National Park Service, Fort Collins, Colorado.

NPS 641/100681, November 2009

Contents

Figures

Page

Tables

Page

Appendixes

Page

Executive Summary

The mission of the National Park Service is "to conserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment of this and future generations" (NPS 1999). To uphold this goal, the Director of the NPS approved the Natural Resource Challenge to encourage national parks to focus on the preservation of the nation's natural heritage through science, natural resource inventories, and expanded resource monitoring (NPS 1999). Through the Challenge, 270 parks in the national park system were organized into 32 inventory and monitoring networks.

The San Francisco Bay Area Network (SFAN) includes Golden Gate National Recreation Area (GOGA), John Muir National Historic Site (JOMU), Pinnacles National Monument (PINN), and Point Reyes National Seashore (PORE). The network has identified vital signs, indicators of ecosystem health, which represent a broad suite of ecological phenomena operating across multiple temporal and spatial scales. Our intent has been to monitor a balanced and integrated "package" of vital signs that meets the needs of current park management, but will also be able to accommodate unanticipated environmental conditions in the future. Salmonids represent a particular high priority vital sign for SFAN because they are ecologically significant, have endangered or threatened status, and are of high interest to the public.

The National Park Service has conducted fisheries monitoring of watersheds in Point Reyes National Seashore (PORE), Golden Gate National Recreation Area (GOGA), and Muir Woods National Monument (MUWO) that contain coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*). These watersheds, including Olema Creek, Redwood Creek and Pine Gulch Creek represent the majority of salmonid-bearing streams in Marin County, California, and support the southernmost stable populations of coho salmon on the western Pacific Coast. These monitoring efforts, conducted with support through the NPS Inventory and Monitoring Program and California Department of Fish and Game, have supported multiple life stage monitoring of coho salmon in coastal Marin watersheds since 1998. This report presents a summary of results from adult escapement surveys, outmigrant smolt trapping, summer index reach monitoring, and basinwide coho juvenile population estimates for Olema, Redwood, and Pine Gulch Creeks. Performed in conjunction with winter spawner surveys and summer juvenile surveys, the spring outmigrant surveys on Olema, Pine Gulch, and Redwood Creeks permit an evaluation of abundance and survival associated with the freshwater portion of their life-cycle. Monitoring results for 2007 track different life stages of the three coho cohorts.

During the 2006-2007 spawner surveys, reduced numbers of spawners were observed for this year class when compared to 2003-2004. Olema Creek watershed redd numbers, which takes into account John West Fork, declined by 13%. Redwood Creek mainstem had a 51% decline in total coho redd production from the previous year class. Of the four consecutively monitored years of this cohort on Redwood Creek, 2006-2007 had the lowest coho spawning activity. On Pine Gulch, no spawning activity was observed. Based on juvenile population estimates made during the summer of 2004 and smolt production estimates calculated during the spring of 2005, the reduced escapement was likely caused by poor ocean conditions.

Although the 2006-2007 had reduced escapement, the 2007 calculated juvenile population estimates for both Olema Creek (31,936 ± 4,122) and Redwood Creek (7,832 ± 1,640) were the highest on record suggesting above average spring survival for both creeks. On Pine Gulch Creek no coho were detected while performing juvenile coho surveys marking the first missing

year class since the recolonization of Pine Gulch was documented in 2001. Although the calculated 2007 smolt production estimates for all three watersheds were lower than average, survival rates from egg to smolt were higher than average.

Smolt outmigration observed in spring 2007 were small, when compared with other years, but represented relatively high overwinter survival when compared with summer 2006 population estimates. The Olema Creek outmigration estimate of 1,098 ± 116, indicated a juvenile to smolt survival estimate of 61.2%. The Redwood Creek outmigration estimate of 520 ± 126, indicates that the juvenile to smolt survival for this year class was 49.5%. In Pine Gulch Creek, the 219 ± 33 coho smolts represented nearly 75% of the total summer 2006 juvenile estimate (295 ± 201). These outmigration totals indicate strong overwinter survival, likely due to a mild winter.

Acknowlegements

We wish to thank the numerous volunteers who helped us with the fieldwork throughout the year. Assistance was also provided by the Conservation Corps North Bay (formerly Marin Conservation Corps). The California Department of Fish and Game provided funding through contract number: P0530415. Support was also provided by the Point Reyes National Seashore Association.

1 - Introduction

The National Park Service has been monitoring salmonid fish within the Olema Creek, Pine Gulch Creek, and Redwood Creek watersheds in coastal Marin County since 1997. Much of this has been conducted by Golden Gate National Recreation Area and Point Reyes National Seashore. The California Department of Fish and Game (DFG) has made significant contributions to the Point Reyes National Seashore Association to support this work. The primary focus of the DFG monitoring grants have been to document federally and state listed endangered coho salmon (*Oncorhynchus kisutch*) population distribution and trends within these watersheds. In addition, monitoring has been conducted to document information of federally threatened steelhead trout (*O. mykiss*) and other fish species within the monitored watersheds. Most recently, the monitoring program has become an integral part of the San Francisco Bay Area Inventory and Monitoring (I&M) Program (Adams et al. 2006).

The SFAN I&M program has selected a variety of ecological indicators that will help track environmental conditions and inform the parks about management. Along with monitoring salmonids, the I&M program is developing monitoring protocols on a variety of related indicators including water quality and stream flow. The San Francisco Bay Area Network Draft Stream Fish Monitoring Protocol version 3.2 documents methods used by the National Park Service (NPS) in salmonid monitoring within coastal Marin County since 1997 (Ketcham et al. 2007).

This report includes summary results of adult escapement, smolt trapping, habitat surveys, index reach surveys, and basinwide snorkel surveys for Olema Creek, Pine Gulch Creek, and Redwood Creek conducted during 2007, and summarized in comparison with all previous years of monitoring. In addition, Appendix B includes results of 2007 general systematic sampling data collected on John West Fork, Giacomini Creek, Quarry Gulch, Cheda Creek, and Bear Valley Creek. These watersheds are located within the Lagunitas Creek and Bolinas Hydrologic Sub-Areas (HSA) of the Bodega and Marin Hydrologic Units. The Recovery Strategy for Coho Salmon (CDFG 2004) categorizes each of these HSAs as high priority restoration areas for coho salmon. The monitoring efforts conducted through this program contribute to our understanding of population dynamics and condition within the coastal Marin County Area (Figure 1).

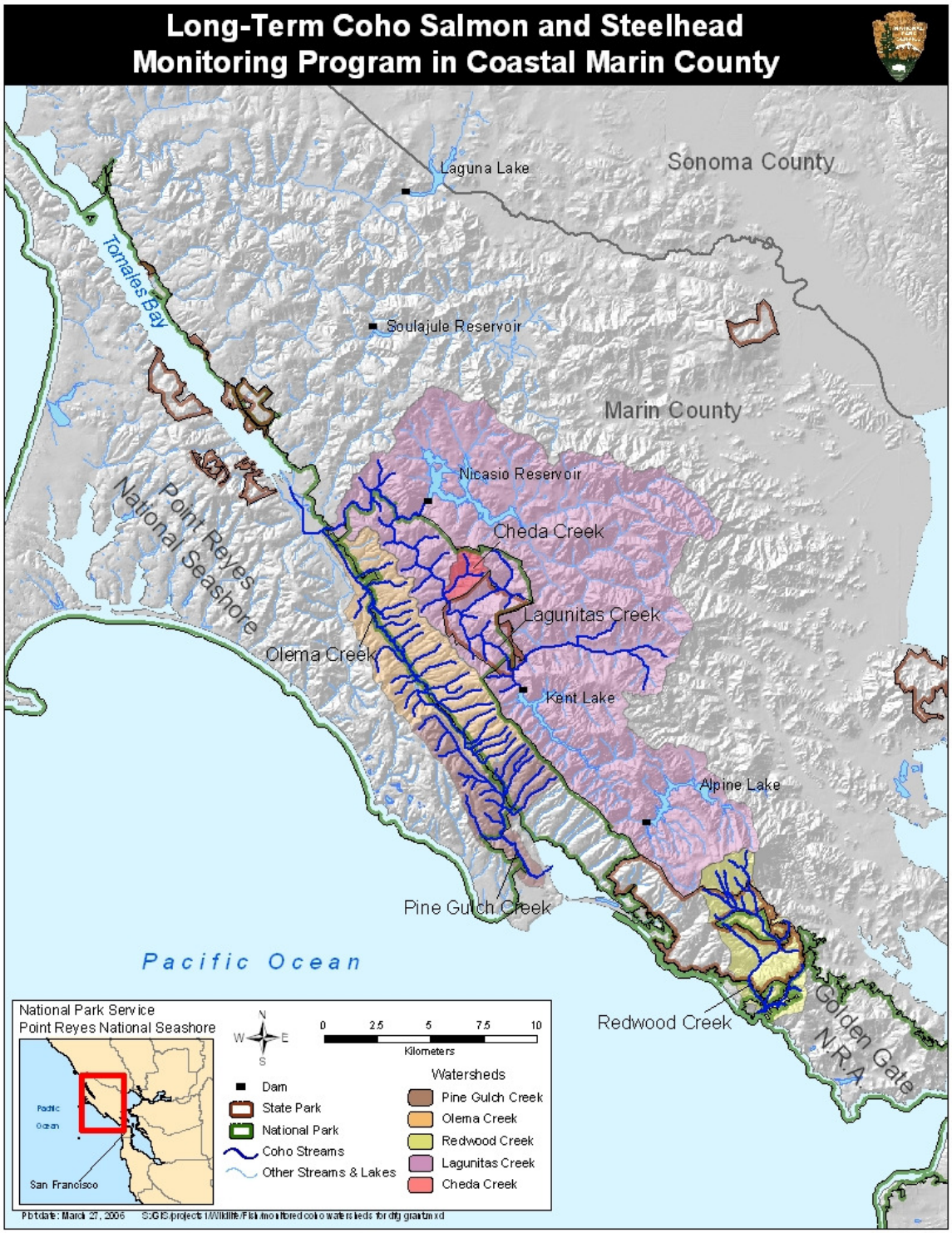


Figure 1. Streams supporting coho salmon in coastal Marin County.

1.1 Background

Spawning populations of coho salmon and steelhead trout have declined significantly from historic numbers in the coastal streams of central California. It has been estimated that existing naturally spawning coho salmon stocks comprise only 1% of their historical number along the west coast and that as much as 46% of California's coho salmon populations have been extirpated from their watersheds (Brown et al. 1994).

Dramatic declines in salmonid populations throughout coastal watersheds have occurred with changes in watershed condition as a result of land use and development. Salmonids require connected surface flow for migration and dispersal (dams and culverts typically are barriers), cold temperatures (<70 Fahrenheit) and high dissolved oxygen levels. While most salmonids have been affected by watershed development, coho salmon are particularly susceptible due to their, semelparous (spawn once) three year life cycle requiring an entire year of residence in the freshwater prior to smolting and migrating to the ocean. Although steelhead also require year-round high quality water, their ability to spawn more than once and to reside in either freshwater or marine systems for variable lengths of time allows the species far greater ability to adjust to changing watershed conditions.

Based on historic regional accounts, numbers of coho salmon and steelhead trout have been severely depleted. Coastal Marin County streams and their associated watersheds currently containing populations of coho salmon and steelhead trout include Olema/Lagunitas Creek, Redwood Creek, and Pine Gulch Creek. Some of the factors believed to have contributed to the declines in anadromous fish runs within the parks include:

- Dam construction and loss of hydrologic connectivity;
- Historic logging and sediment delivery to the channel;
- Removal of large woody debris and limited riparian areas;
- Stream channel and habitat alteration;
- Loss of spawning and rearing habitat;
- Water withdrawals, extreme hydrologic and climatic events; and
- Marine over-harvesting and poor ocean productivity.

1.2 Fish Resources

The primary species monitored through this program are coho salmon and steelhead trout. However, other aquatic species including sculpin, roach, lamprey, and stickleback are captured and documented through our monitoring efforts.

1.2.1 Coho Salmon

The general biology of coho salmon is described in detail in Hassler (1987) and Sandercock (1991). The coho salmon is an anadromous, semelparous fish species, migrating from marine water back to freshwater for a single chance at reproduction. Coho generally return to natal streams after spending two years in the ocean. The spawning migrations begin after heavy late-fall or winter rains breach the sandbars at the mouth of coastal streams allowing the fish to move upstream. Spawning occurs in small to medium sized gravel at aerated sites, typically near the head of a riffle (Moyle 1976). These streams have summer temperatures seldom exceeding 21 degrees Centigrade (70 degrees Fahrenheit). Emergent fry use shallow near-shore areas, whereas optimal habitat conditions for juveniles and sub-adults are deep pools associated with rootwads, woody debris, and boulders in shaded stream sections (Laufle et al 1986). The distribution and habitat of coho juveniles partially overlaps with that of the California red-legged frog.

Because of dramatic declines in population numbers, the National Marine Fisheries Service (NMFS) was petitioned to list this species coastwide (Federal Register 1996). Several runs were listed along the central California coast and include regions occupied by California red-legged frogs. Causes of coho salmon declines in California include incompatible landuse practices such as logging, ranching, and urbanization, loss of wild stocks, introduced diseases, over harvesting, and climactic changes.

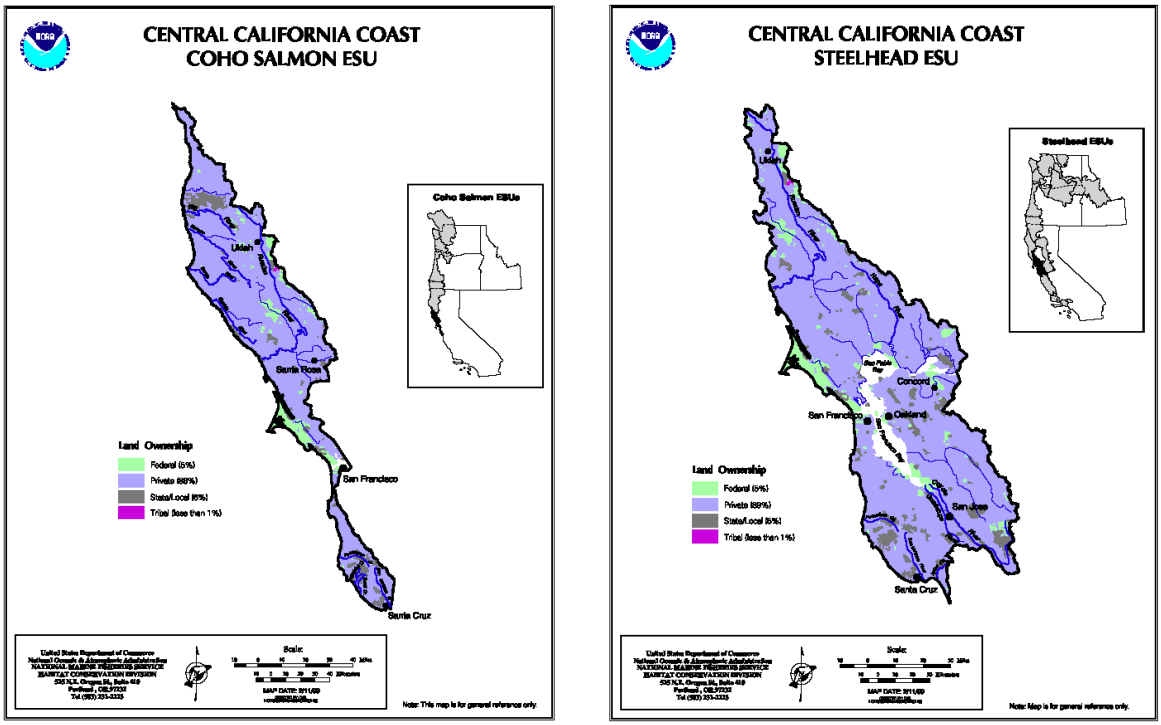
Coho salmon are known to exist in watersheds including Lagunitas, Olema, Pine Gulch (Brown and Ketcham 2002), and Redwood Creeks. Walker Creek, which flows into Tomales Bay, likely supported coho salmon and is part of a larger coho recovery program conducted by the California Department of Fish and Game and NOAA-Fisheries.

Regulatory Protection (NOAA Fisheries): Coho salmon were listed as a threatened species within the central California coast coho salmon ESU (CCCESU) on October 31, 1996 by the National Marine Fisheries Service (NOAA-Fisheries) (Federal Register 1996). The CCCESU (Figure 2) includes all naturally spawned populations of coho salmon from Punta Gorda in northern California south to and including the San Lorenzo River in central California, as well as populations in tributaries to San Francisco Bay, excluding the Sacramento-San Joaquin River system. The original listing criteria stated that the Lagunitas/Olema Creek population accounted for more than 10% of the wild coho population (Brown et al 1994) in the CCCESU. Recent research through the NPS, Marin Municipal Water District (MMWD), and Salmon Protection and Watershed Network (SPAWN) has shown that the Lagunitas population likely represents more than 20% of the CCCESU population.

In association with the coho threatened listing NOAA-Fisheries designated critical habitat for coho salmon on May 5, 1999 (Federal Register 1999). The critical habitat is designated to include all river reaches accessible to listed coho salmon from Punta Gorda in northern California south to the San Lorenzo River in central California, including Mill Valley (Arroyo Corte Madera Del Presidio) and Corte Madera Creeks, tributaries to San Francisco Bay. Excluded are areas above specific dams or above longstanding, naturally impassable barriers (i.e., natural waterfalls in existence for at least several hundred years). Major river basins containing spawning and rearing habitat for this ESU comprise approximately 4,152 square miles in California. The following counties lie partially or wholly within these basins: Lake, Marin, Mendocino, San Mateo, Santa Clara, Santa Cruz, and Sonoma.

In their 2001 Status Review, NOAA-Fisheries acknowledged that within the CCCESU, the decision to list coho salmon as threatened may have been overly optimistic, concluding that the ESU population was presently endanger of extinction (NMFS 2001). As a result of these and further findings, NOAA-Fisheries completed a rulemaking process in June 28, 2005, which downgraded the coho status (upgraded listing protection) in the ESU to Endangered (Federal Register 2005).

Regulatory Protection (California Department of Fish and Game): On April 5, 2001, the Fish and Game Commission accepted the petition to list coho salmon north of the Golden Gate as endangered under the State Endangered Species Act. As a response to this petition, the DFG



prepared a status review of California which concluded that the coho salmon within the central California coast ESU (as designated by NOAA Fisheries – Figure 2) are in serious danger of becoming extinct throughout all or a significant portion of its range, and that the endangered listing is warranted (CDFG 2002). As a response, the CDFG released a draft Recovery Strategy for coho salmon in November 2003, which was adopted as revised by the Fish and Game Commission on February 6, 2004. On August 5, 2004, the Fish and Game Commission added coho salmon populations between San Francisco and Punta Gorda to the list of species protected under the Endangered Species Act (areas south of San Francisco were already listed as endangered). This listing became effective March 30, 2005.

Figure 2. Central California Coast Coho Salmon Evolutionarily Significant Units (ESU) (left) and Central California Coast Steelhead ESU/Distinct Population Segment as identified by NOAA Fisheries. Marin County is included within the Central California Coast ESU for coho salmon and steelhead.

1.2.2 Steelhead

Steelhead are the anadromous form of rainbow trout. Adult steelhead typically spawn in gravel riffles in the spring, from February to June. Steelhead are multiparous, meaning they can spawn more than once. Research conducted in the 1950s documented female steelhead returning to spawn in multiple years (Shapavolov and Taft 1954). Optimum temperatures for growth range from 13 to 21 degrees Centigrade (55 to 70 degrees Fahrenheit) (Moyle 1976). It is also noted that steelhead may persist in a broad range of pH (from 5.8 to 9.6) but prefer a pH between 7 and 8 (Moyle 1976). Steelhead fry reside in near-shore areas. Steelhead juveniles tend to use riffles and pool margins. Because of dramatic declines in population numbers, the National Marine Fisheries Service (NMFS) was petitioned to list this species throughout much of the California coast. Steelhead trout are known to exist in most perennial watersheds within Marin County.

Regulatory Protection: Steelhead were listed as a threatened species on August 17, 1997 (Federal Register 1997). As of February 6, 2006 the former steelhead Evolutionary Significant Unit has been changed to a Distinct Population Segment (DPS). The central California coast steelhead DPS includes all naturally spawned populations of steelhead (and their progeny) in California streams from the Russian River (inclusive) to Aptos Creek (inclusive), and the drainages of San Francisco, San Pablo, and Suisun Bays eastward to Chipps Island at the confluence of the Sacramentao and San Joaquin Rivers; excluding the Sacramento-San Joaquin River Basin. The artificially propagated stocks from the Don Clausen Fish Hatchery and the Kingfisher Flat Hatchery/Scott Creek are also included (Federal Register 2006). As of the 2006 Federal Register, only ocean-run *O. mykiss* (steelhead trout, not resident rainbow trout) are protected under the ESA. In 2000, critical habitat was designated for steelhead along the California coast. In 2002 these designations were withdrawn due to a National Marine Fisheries Service (NMFS) decree and weren't reinstated until a final ruling in August 2005. This critical habitat became effective January 2, 2006 (Federal Register 2006). Critical habitat only encompasses the *O. mykiss* anadromous range.

1.2.3 Chinook Salmon

California Coastal Chinook salmon were listed as threatened on September 16, 1999; threatened status reaffirmed on June 28, 2005. The ESU includes all naturally spawned populations of Chinook salmon from rivers and streams south of the Klamath River to the Russian River, California. Though not included in the listed area, adult Chinook salmon have been observed within Lagunitas Creek in increasing numbers since 2000 (MMWD 2006). The increasing frequency of Chinook salmon within Lagunitas Creek may indicate the development of a self-sustaining population, but whether this will persist is unclear (NOAA Fisheries 2004). Because of the proximity of these fish to the southern boundary of the ESU, NOAA Fisheries has treated this watershed population as part of the California Coastal listed population for the purposes of other consultations on the lands of Point Reyes National Seashore and Golden Gate National Recreation Area (NOAA Fisheries 2004).

1.2.4 Essential Fish Habitat

The Magnuson-Stevens Fishery Conservation and Management Act, as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267) requires all Federal agencies to consult with NMFS on all actions, or proposed actions, permitted, funded, or undertaken by the agency, that may adversely affect Essential Fish Habitat (EFH). EFH is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." "Waters" include aquatic areas and their associated physical, chemical and biological properties. "Substrate" includes sediment underlying the waters. "Necessary" means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem. Spawning, breeding, feeding, or growth to maturity covers all habitat types utilized by a species throughout its life cycle. NMFS would provide recommendations to conserve EFH to Federal or state agencies for activities that would adversely affect EFH.

1.3 Monitoring Rationale

Salmonid reproduction rates are high, matching the rates of mortality that occur throughout their life cycle. In freshwater systems, mortality rates for coho juveniles typically peak in early summer and stabilize by the fall. By winter, mortality rates generally begin to increase with higher flow events, peaking in the spring as fish smolt and move downstream (Chapman 1965; Manning 2001). In the north coast of California and Oregon, researchers have observed high juvenile densities in the summer, followed by very low smolt outmigration the following spring

(Duffy 2004 personal communication). In the north coast of California and Oregon, monitoring has shown that in areas where adult escapement is adequate to seed watersheds, the production of coho smolts is likely limited by winter habitat availability and overwinter survival (Nickelson et al 1998).

Our monitoring of multiple life stages will help characterize potential population bottlenecks in the watershed. Observation of adult escapement and redd density, juvenile density in the summer months, and smolt outmigration allows us to track cohorts through documented bottlenecks and identify if and where watershed-specific limiting factors may exist.

1.3.1 Monitoring Questions

This monitoring program was developed to answer the following questions:

- What is the change in the number of watersheds over time that support salmonids within the SFAN?
- What are the changes in species densities at preexisting index reach locations on Redwood, Olema , and Pine Gulch Creeks?
- What habitat constraints exist in the parks that currently impede or limit salmon recovery efforts?
- Are parks meeting resource protection mandates relative to salmonid habitat protection?
- Is the condition (e.g. length, weight, presence of abnormalities) of fish changing over time?
- What is the annual production of juvenile coho salmon outmigrants in Redwood, Olema, and Pine Gulch Creeks?
- What is the annual escapement of returning adult coho salmon in Redwood, Olema, Pine Gulch, and Cheda Creeks?
- What is the annual abundance of juvenile coho salmon rearing within Redwood, Olema, and Pine Gulch Creeks at summer base flow conditions?

The following questions may be answered in part by this monitoring program but additional information will need to be gathered:

- Where do non-native aquatic species (fish or crayfish) occur, and how do they affect native populations?
- What are the fish populations and community assemblages within SFAN stream systems?
- What is the distribution, condition, and health of non-salmonid fish within SFAN stream systems?
- What is the population genetic structure and age-size relationship for salmonids?
- What is the survivorship between life stages for each coho cohort within Redwood, Olema, and Pine Gulch Creeks?
- How do population trends at GOGA and PORE compare with other watersheds in the region?
- What are the changes in timing and distribution of salmonid spawning, adult sex ratios, and escapement estimates in select streams at PORE and GOGA.
- What are the overall population trends of each coho salmon cohort within GOGA and PORE watersheds?

1.3.2 Monitoring Objectives

1) Conduct winter survey at Olema, Pine Gulch, Redwood, and Cheda Creeks by counting numbers of spawners, carcasses, and redds along spawner reaches to determine long-term trends in distribution and abundance, size (length and weight) of spawning coho salmon.
2) Conduct spring surveys at Olema, Pine Gulch, and Redwood Creeks by smolt trapping near creek mouths of Olema, Pine Gulch, and Redwood creeks to determine long-term trends in abundance of smolt coho salmon and steelhead trout.
3) Conduct summer surveys at Olema, Pine Gulch, and Redwood Creeks by conducting basinwide snorkel surveys to determine long-term trends in distribution and abundance of juvenile coho salmon.
4) Conduct summer surveys at Olema, Pine Gulch, Redwood, Franklin, and Easkoot Creeks at preexisting index reaches to determine long term trends in density, size, and age composition of coho salmon and steelhead trout.
5) Identify gross changes in habitat (pool:riffle) in Olema, Pine Gulch, and Redwood Creeks during summer/fall surveys.

1.4 Watershed Background

1.4.1 Olema Creek

Olema Creek is the largest undammed watershed in coastal Marin County, California and an important stream for coho salmon and steelhead within the CCCESU. The 15.9 km stream flows northwest through the Olema Valley, the landward expression of the San Andreas Fault Zone. It's confluence with Lagunitas Creek lies at the head of the ecologically significant Tomales Bay. Protected from development, the 14.5 square mile watershed is primarily contained within the boundaries of Point Reyes National Seashore and the Golden Gate National Recreation Area North District. The watershed provides habitat to four federally protected aquatic species (California freshwater shrimp – endangered; coho salmon – endangered; steelhead – threatened; California red-legged frog – threatened). Olema Creek is the focal point of hydrologic, water quality, and fisheries monitoring within Point Reyes National Seashore.

1.4.2 Cheda Creek

Cheda Creek is a small perennial tributary of the Lagunitas Creek watershed and provides critical habitat for steelhead trout and coho salmon. Past land-use within the Cheda Creek drainage has resulted in serious alterations to the natural hydrologic and riparian condition of the creek. These factors have negatively impacted salmonid populations, water quality, and the ability of the aquatic ecosystem to function properly. The construction of a fish passage structure in the fall of 2000 was part of an overall watershed restoration project initiated by the National Park Service (NPS) to restore the system to a more natural and sustainable condition.

1.4.3 Redwood Creek

Redwood Creek is a 7.5 square mile coastal watershed in southern Marin County, California. Redwood Creek flows southwest from the flanks of Mt Tamalpais, through Muir Woods National Monument, discharging to the Pacific Ocean through Big Lagoon at Muir Beach, CA. Protected from development, the watershed is primarily contained within the boundaries of Mt Tamalpais State Park, Golden Gate National Recreation Area and Muir Woods. The watershed provides habitat to coho salmon – endangered; steelhead – threatened; and the California red-

legged frog – threatened. Redwood Creek supports a genetically distinct sub-group of coho salmon (Garza and Gilbert-Horvath 2003) within the CCCESU.

1.4.4 Pine Gulch Creek

Pine Gulch Creek drains a 7.5 square mile watershed in coastal Marin County, California, and is the primary freshwater input to Bolinas Lagoon. Pine Gulch Creek is located within the CCCESU where coho salmon and steelhead occur. The watershed supports a population of steelhead and it is generally accepted that it supported a native self-sustaining population of coho salmon into the 1970's. It is likely that the drought of the late 1970's coupled with in-stream damming during the same period severely depleted multiple year classes and led to unsuitable conditions for continued survival of the species within the Pine Gulch watershed. In 2001, NPS documented the return of coho salmon to the watershed beginning with the recovery of a coho carcass, and subsequent documentation of coho juveniles in the watershed the following summer (Brown and Ketcham 2002).

2 - Sampling Design and Methods

This program includes strategies to monitor salmonids at a variety of life stages. Methods for adult spawner surveys, outmigrant smolt trapping, summer juvenile index reach surveys, and a basinwide coho juvenile population estimate are documented in the draft San Francisco Bay Area Network Stream Aquatic Resource Monitoring Protocol (NPS 2003). These methods have been used by the National Park Service (NPS) for salmonid monitoring within coastal Marin County since 1997. Many of the methods associated with the project are consistent with draft California Department of Fish and Game biotic monitoring guidelines (Collins 2003).

2.1 Adult Escapement Surveys

Annually, spawner surveys are conducted in watersheds within and adjacent to SFAN Park units, including Point Reyes National Seashore (PORE), Golden Gate National Recreation Area (GOGA), and Muir Woods National Monument (MUWO). These surveys concentrate primarily on federally endangered coho salmon (*Oncorhynchus kisutch*) and federally threatened steelhead (*O. mykiss*). The watersheds within Coastal Marin County and summarized in this report, including Olema Creek, Redwood Creek, and Pine Gulch Creek (see Figure 1) are considered to support the most southerly stable populations of coho salmon.

The Coho and Steelhead Restoration Project (CSRP) was initiated in 1997 and continued the work began by the Tomales Bay Association (TBA) and previous NPS biologists with comprehensive surveys of Olema Creek, Redwood Creek, Cheda Creek (a Lagunitas Creek tributary) and Devil's Gulch (a Lagunitas Creek tributary) in the winter of 1997. To increase the value of the information collected during spawning surveys, and enable comparison of data from year to year, the CSRP began efforts to standardize methods and test different survey methodologies. Marin Municipal Water District (MMWD) took over surveys on Devil's Gulch starting in the winter of 2000. Spawner surveys in Pine Gulch documented the return of coho during the winter of 2000-2001. In 2003, the fisheries monitoring efforts were incorporated into the San Francisco Bay Area Network (SFAN) Stream Aquatic Monitoring Program. Protocols to document field and analytical methods have been developed for the adult escapement monitoring efforts (Ketcham et. al 2005).

2.1.1 Rationale for Sampling Design

The methodologies currently used for spawner surveys have been used to estimate escapement for a variety of salmonids throughout the Pacific Northwest (Johnston et al. 1987; Irvine et al. 1992; Anderson and McGuire 1994; Downie and Peterson (undated)). Although both steelhead and coho are present in PORE and GOGA watersheds, the surveys focus on coho because their life history pattern and behavior is more amenable to accurate data collection. Coho spawner survey data tends to be more accurate than steelhead information because: coho spawn earlier than steelhead (typically in December or January), coho remain in the watershed until they die after spawning, which makes carcasses readily collectible, and steelhead spawn over a longer period of time than coho (from January to May) making frequent data collection more difficult.

2.1.2 Field Methods

NPS staff and trained volunteers conduct surveys each winter during the coho spawning season to quantify escapement and determine spawning density and distribution. Although surveys focus on coho, steelhead spawners and redds are also observed and counted. Surveys are conducted approximately every week, although storms and high stream flows often dictate less frequent surveys. Teams of two to four observers walk upstream through 2-4 km reaches, along creek

margins and banks where possible, and look for live fish, carcasses, and redds. Live fish are identified to species and sex, and lengths are visually estimated. Carcasses are measured (fork length), identified to species and sex, and marked to prevent double counting. Carcass scales and tissue samples are collected for age and genetic analysis. Scales samples are only collected from fresh (both eyes are still clear) carcasses that have not been mauled by scavengers. Redds are measured and marked with flagging. Because redds are stationary and can be observed over time, redd monitoring is targeted to determine spawning success.

Particular care is taken not to disturb redds or actively spawning adults. Locations of all live fish, carcasses and redds are recorded in reference to permanent tags placed every 100 meters along each stream. The survey data is used to generate index values and minimum population estimates for the assessment of long term trends.

Because coho return to spawn over a one to three-month period November through January (weather dependent) and residence time on the spawning grounds is variable, live fish may be double counted during repeated surveys. Reported spawning escapement estimates are made using the Peak Live + Cumulative Dead (PLD) index. This index is derived by adding the peak number of live fish observed during a single survey to the number of carcasses recovered on or prior to that date. Carcass information is also used to calibrate observer length and sex estimates. Redd counts are used to describe spawning density and spatial distribution. Where survey frequency is adequate, reporting will include escapement estimates using the Area Under the Curve (AUC) method (Irvine et al. 1992). AUC estimates provide an estimate that takes into account the observed residence time and observer efficiency that was encountered throughout the spawner survey. AUC estimates usually provide a more robust escapement estimate than PLD estimates especially during years with high returns of adult spawners and runs with multiple spawning peaks.

2.1.3 Olema Creek

A large section of the mainstem of Olema Creek, 17.6 km, has been surveyed by the Tomales Bay Association (TBA), PORE staff, and volunteers since 1993. The section is currently divided into 7 survey reaches starting one kilometer above the confluence with Lagunitas Creek and ending at the Highway 1 culvert at milepost 19.94. Reaches are delineated to facilitate sampling based on access, length, and the existence of permanent landmarks for reach boundaries (Figure 3). The existing seven reaches extend from:

1) One kilometer above the confluence with Lagunitas Creek to the Bear Valley Road Bridge in the town of Olema (1.6 km).
2) The Bear Valley Bridge to the confluence with Truttman Creek (3.2 km).
3) Truttman Creek to the horse trail crossing at the Stewart Ranch (2.6 km).
4) Stewart Ranch to the first Hwy. 1 bridge at Five Brooks (1.3 km).
5) Five Brooks to the abandoned Lime Kilns (2.8 km).
6) The Lime Kilns to the abandoned Randall ranch House (1.7 km).
7) The Randall House to the HWY. 1 culvert at milepost 19.94 (4.1 km).

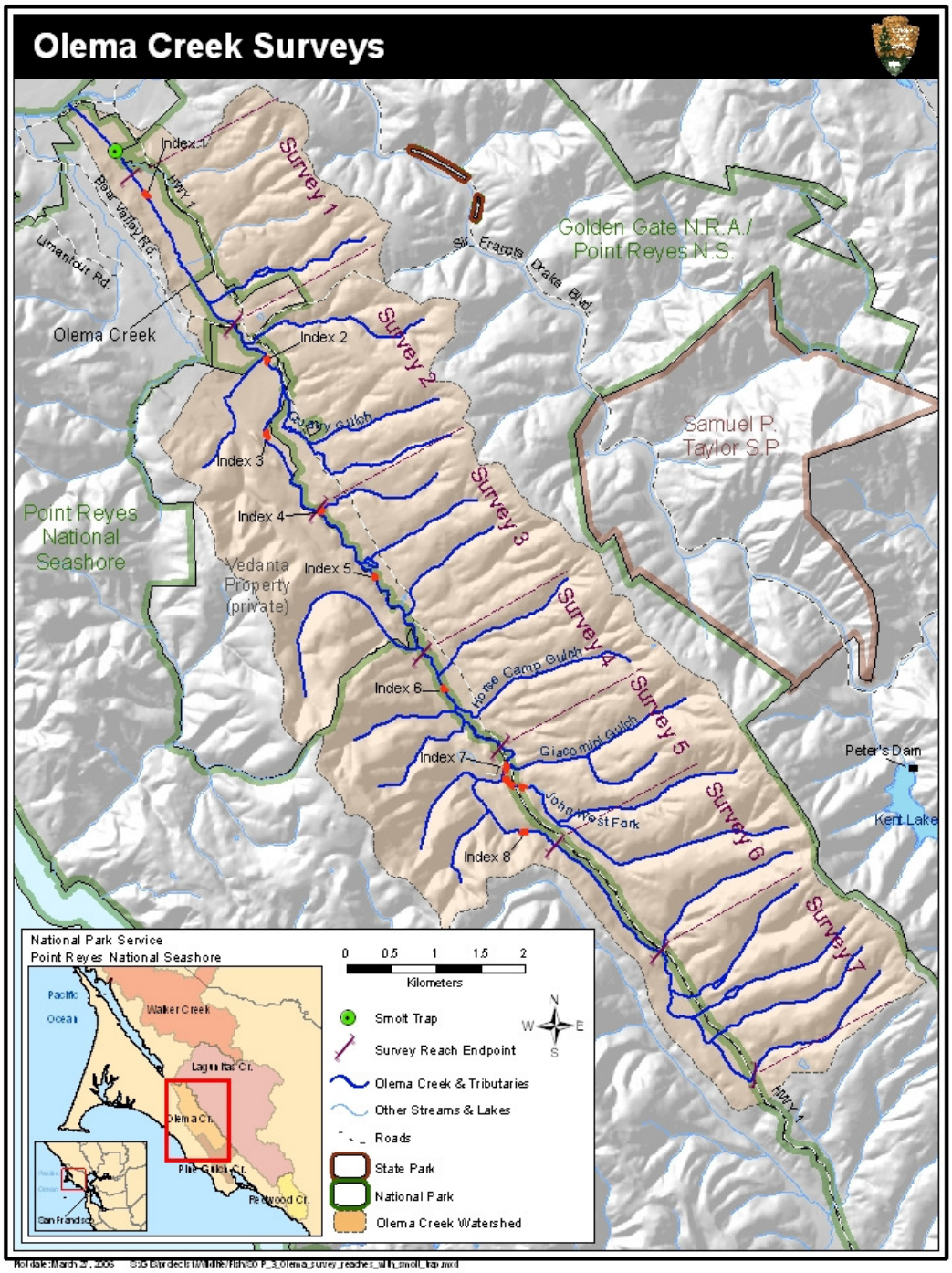


Figure 3. Olema Creek spawner survey reach map.

In addition to the mainstem of Olema Creek, surveys are often conducted on some of the larger tributaries. Most tributary surveys conducted in the past were intended only to establish presence or absence of spawning coho and reach lengths varied widely. At present, complete surveys are conducted for the tributaries as personnel and flow conditions allow, based on order of priority. For each tributary, survey reaches start at the mouth and generally continue upstream as long as no passage barriers exist or no more spawning activity is detected. The tributaries, many of them

unnamed on U.S. Geological Survey (USGS) 7.5 minute maps, are named in Figure 3 and listed in order from downstream to upstream:

1) Quarry Gulch located close to the Olema Cemetery 4.1 km above the mouth of Olema Creek at Hwy. 1 milepost 25.35.
2) Boundary Gulch located 8.3 km above the mouth of Olema Creek at Hwy. 1 milepost 24.30.
3) Horse Camp Gulch located 9.6 km above the mouth of Olema Creek at Hwy. 1 milepost 23.26.
4) Giacomini Gulch located 10.8 km above the mouth of Olema Creek at Hwy. 1 milepost 22.78.
5) John West Fork located 10.9 km above the mouth of Olema Creek at Hwy. 1 milepost 22.67. (survey reach from trib mouth to 2 km upstream)

2.1.4 Lagunitas Creek Watershed - Cheda Creek

Lagunitas Creek and its tributaries (Nicasio Creek, San Geronimo Creek, Devil's Gulch, Cheda Creek, Bear Valley Creek, and Olema Creek) drain more than 230 square kilometers of western Marin County. The headwaters of the Lagunitas Creek mainstem lie within the 53,000 ha watershed lands administered by Marin Municipal Water District (MMWD). The mainstem originally totaled about 40 km of perennial stream draining the northern slope of Mt. Tamalpais, but was reduced by more than 50% by construction of Alpine Dam in 1918 and Peters Dam in 1953. Because neither dam has provision for fish passage, their construction resulted in permanent loss of the upper portion of the drainage to anadromous fish.

The portions of the Lagunitas drainage most significant for salmonids are under a number of ownerships. Approximately 12 km of the mainstem is bordered by NPS lands (north district Golden Gate National Recreation Area). A major tributary, San Geronimo Creek, flows through privately held land in San Geronimo Valley. Devil's Gulch lies almost entirely within Samuel P. Taylor State Park with its headwaters in NPS lands. Only one smaller tributary of Lagunitas Creek, Cheda Creek, lies entirely within GGNRA lands.

Cheda Creek (Figure 4), a Lagunitas Creek tributary, has been surveyed since 1996-1997 to detect the presence or absence of coho. The NPS completed a fish passage project in the fall of 2000, coho salmon spawning in the upper part of the creek above the fish passage project site was detected in the 2004-2005 spawning season. Approximately 1.3 km of stream is typically surveyed, including a 0.8 km reach below the fish passage improvement and 0.5 km reach above.

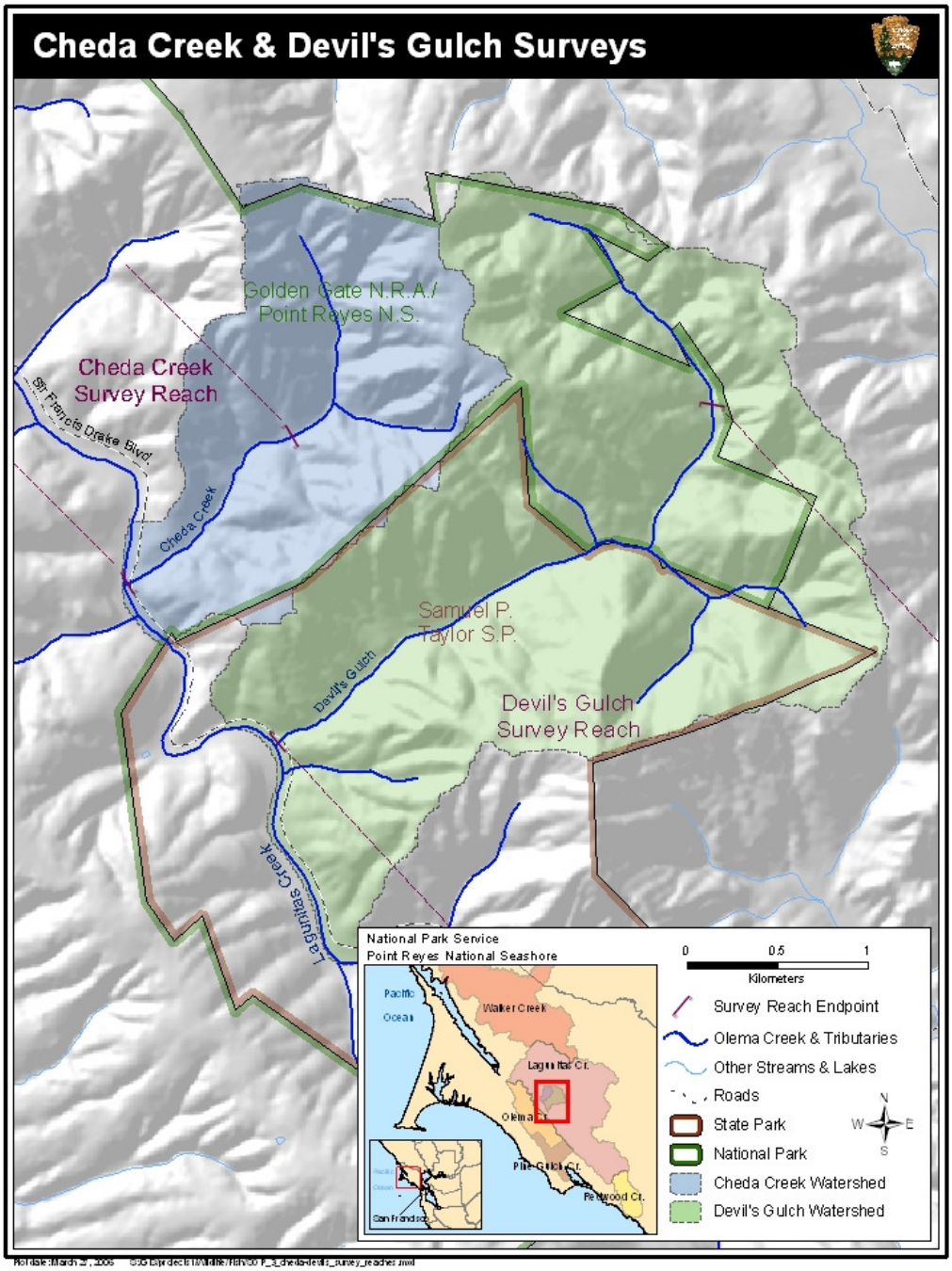


Figure 4. Cheda Creek spawner survey reach map.

2.1.5 Redwood Creek

Since 1994, the NPS has conducted annual surveys along a 6.7 km section of the mainstem of Redwood Creek (Figure 5) between a point 140 m below the Pacific Way Bridge to approximatly 500 m above Bridge 4 in Muir Woods. The section encompasses most of the stream length used by coho salmon. To facilitate sampling, the section is divided into three reaches;

1) Pacific Way Bridge to the Kent Creek confluence in Mt. Tamalpais State Park (2.7 km),

2) Kent Creek confluence to Bridge 1 in Muir Woods (2.4 km) and,
3) Bridge 1 to 500 m above Bridge 4 (1.6 km).

Portions of Fern and Kent Creeks, the two largest Redwood Creek tributaries, were also sampled. The reach on Kent Creek extends from the confluence with Redwood Creek to a water fall, approximately one kilometer upstream, that is impassable to migrating adults. The Fern Creek section has been surveyed since 1994 and extends between the Redwood Creek confluence and a series of steep cascades one kilometer upstream.

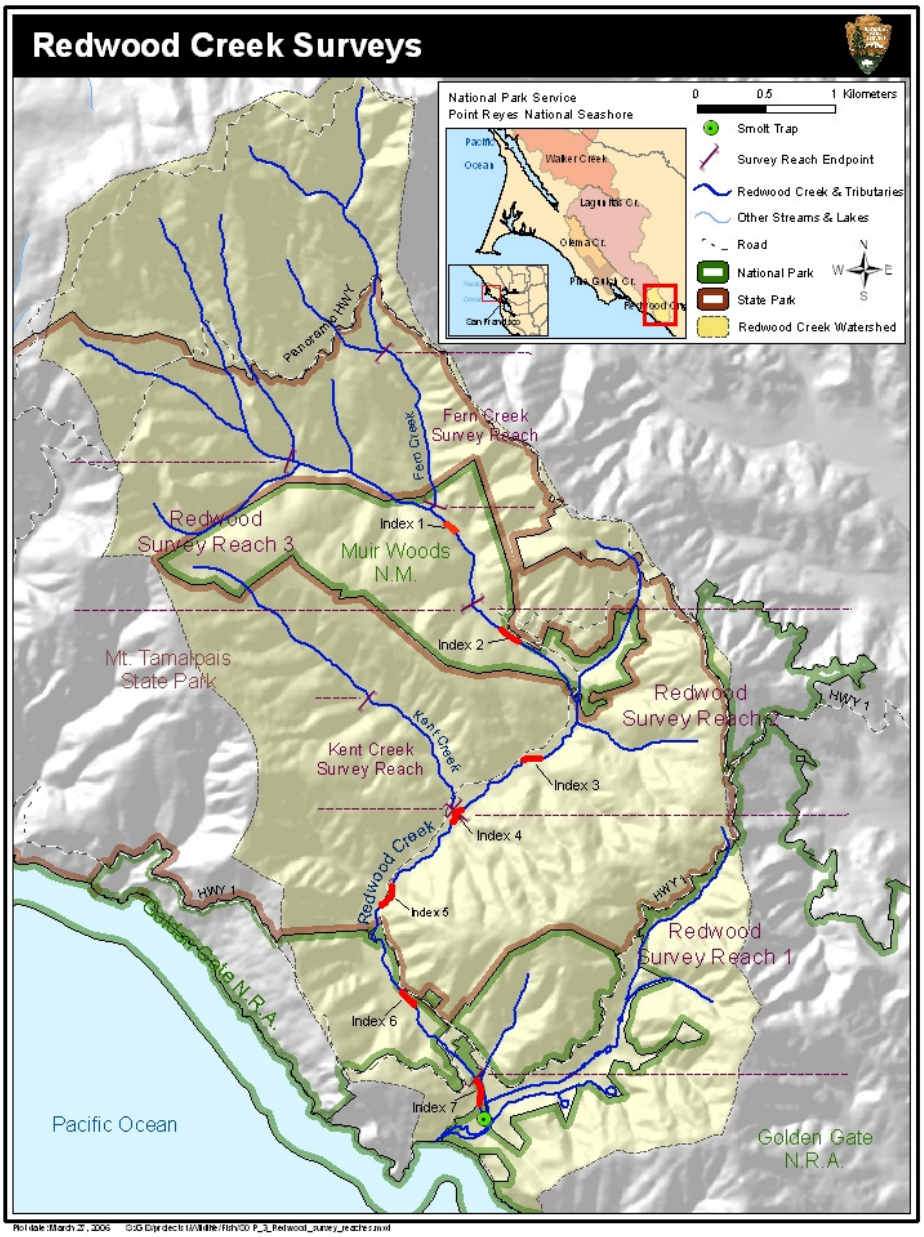


Figure 5. Redwood Creek spawner survey reach map.

2.1.6 Pine Gulch Creek

Since 1997, the NPS has conducted surveys along a 9 km section of the mainstem of Pine Gulch Creek. Coho salmon were first spotted during surveys in the winter of 2000-2001. Due to private property access issues and the nature of the watershed, the survey reaches are longer than normal (Figure 6). This requires a solid day to conduct the survey with two teams.

The spawner surveys start at the Olema-Bolinas Road Bridge and extend upstream to monument marker 100. The section encompasses most of the stream length that would be potentially used by coho salmon.

Currently sampled reaches include:

1) Olema-Bolinas Road Bridge to the Copper Mine Gulch confluence (6.0 km).
2) Copper Mine Gulch– Upstream beyond Teixeira to approximately monument marker 100 (3.5 km).

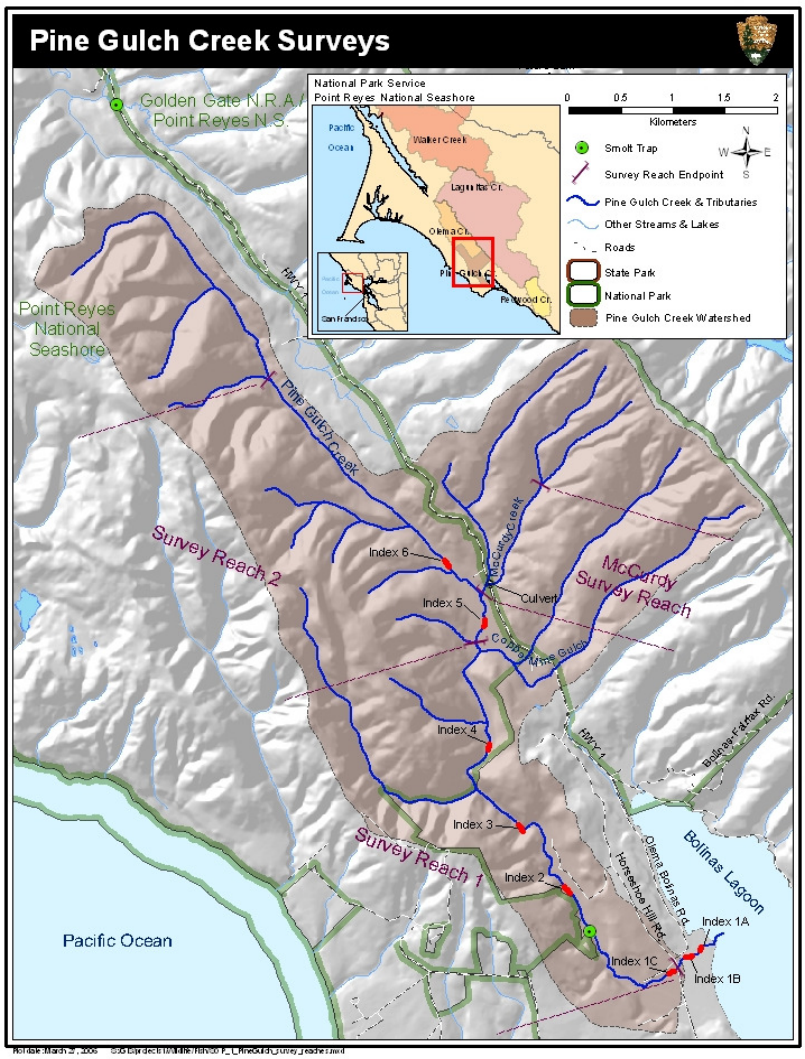


Figure 6. Pine Gulch spawner survey reach map.

2.1.7 Escapement Data Analysis

The analysis of spawner survey data is complicated by annual variability in environmental conditions and run characteristics. Accurate abundance estimates are difficult to generate without counting weirs or other intensive sampling techniques (Irvine et al. 1992). The NPS monitoring program is, nonetheless, interested in developing precise indices of abundance for these small watersheds. Two techniques, Peak Live Plus cumulative Dead (PLD) and Area Under the Curve (AUC) are used to compute index values (Beidler and Nickelson 1980; Johnston et al. 1987). In addition to calculating the indices, we summarized the live fish, redd, carcass, and environmental data for each stream.

The PLD and AUC estimates provide different types of information. The PLD index is derived by adding the peak number of live fish observed during a single survey to the number of carcasses recovered on or prior to that date, and is considered a minimum count. The AUC estimate is calculated using the total number of live fish observed during each survey and the average life of fish on the spawning grounds (residence time). Calculating the area under the curve created by plotting the live fish observations for each survey, produces a quantity termed total fish-days. The area under the escapement curve was given by:

$$\mathbf{AUC = 0.5 \{ \sum (t_i - t_{i-1}) (p_i + p_{i-1})\}}$$

where t_i is the number of days since the first fish entered the survey area and p_i is the total number of fish observed on the i_{th} day (Irvine et al. 1992). Dividing the total number of fish days by the residence time gives the population estimate. Because we did not estimate residence time, separate AUC estimates were computed using the range of values, 8 to 17 days, presented in the literature (Moring and Lantz 1975; Johnston et al. 1987; Irvine et al. 1992). Data collection typically stops after repeated surveys no longer indicate the presence of live coho. High flows prevented us from conducting surveys during significant portions of some spawner seasons. If fish were observed during the last survey of the season, the last date used for calculating the AUC estimate was arbitrarily set at 10 days after the final survey date.

Redd count and location is used to describe spawning density and spatial distribution. Cumulative redd observations are tallied for the spawner year. Redd location is documented by distance upstream and can be compared annually to determine high density spawning reaches. Redd counts may be limited by observer efficiency and changes to the streambed associated with flow events.

2.1.8 Other Monitoring Programs

NPS conducts escapement monitoring on Pine Gulch Creek, Cheda Creek and Redwood Creek as well as Olema Creek. In addition, the Marin Municipal Water District conducts similar monitoring programs on Lagunitas Creek, San Geronimo Creek, and Devil's Gulch. The Salmon Protection and Watershed Network (SPAWN) program conducts surveys on tributaries of San Geronimo Creek. The aggregate of these monitoring efforts provides for detailed escapement results for two of the five coho salmon genetic subgroups within the central California coast ESU.

2.2 Outmigrant Smolt Trap

Outmigrant smolt trapping is performed annually from March thru May on Olema, Pine Gulch, and Redwood Creek. Outmigrant trapping is intended to census the number of coho smolts leaving the watershed. Although trapping operations are focused on coho smolts, smolt trapping

also provides information on steelhead smolt outmigration. Trapping results can also help quantify dates of fry emergence and growth rates through the spring season. Outmigrant traps provide presence/non-detect information and size data for other aquatic species during periods not covered by summer/fall monitoring activities.

2.2.1 Rationale for Sampling Design

At the time of smoltification, coho have spent more than 14 months in the watershed, and steelhead have spent 1-4 years in the system. The response of coho and steelhead populations to changes in habitat quality can not be properly assessed without a measure of smolt production.

Smolt trap monitoring, conducted in conjunction with other life stage monitoring activities, allows the NPS to characterize aggregate watershed productivity for salmonids and permits an evaluation of abundance during three of five distinct freshwater salmonid life stages. The smolt trap information can be compared with adult spawner indices to describe potential ocean productivity and survival. Overwintering survival rates can be assessed by comparing smolt productivity to summer juvenile population estimates. In this manner, change may be detected within each watershed for each monitored salmonid year class. Because coho salmon have a three-year life cycle, monitoring must span this time in order to elicit any type of trend information for the year class. Variation between years of both outmigration and biotic metrics (e.g. weight and length of smolts) can be used to describe the differing conditions and populations of each year class.

2.2.2 Fyke/Pipe Trap Field Methods

Trapping is conducted continually for a 2-3 month period during the spring and requires daily checking by field staff. The fyke/pipe traps used by this program are based on methods developed in northern California for trapping small streams (Manning and Roelofs 1996; Manning 2001) and have proven effective for the current monitoring sites. They are designed to catch fish moving downstream and effectively result in a census of smolt outmigration. Trap sites were determined by location within each watershed, suitable channel morphology, and access.

The fyke/pipe trap on the Olema, Pine Gulch, and Redwood Creeks is based on a design used by CDFG on the Noyo River (Gallagher 2000; Barrineau and Gallagher 2001). A 5’ x 20’ fyke net is supported by t-posts and a frame consisting of 1” galvanized pipe. Several weir panels are constructed consisting of ½” mesh hardware cloth secured with t-posts and zip ties to direct fish into the mouth of the fyke net. A small gap is left between the weir panels and the streambank on one side to allow upmigrating steelhead to pass. The throat of the fyke net is attached to a series of 6” x 20’ PVC pipes, which empty into a plywood trap box. The trap box contains a baffle to further slow water velocity, as well as a mesh divider screen to provide cover and refugia for fry. A bypass channel is provided on one side of the weir to allow adult steelhead to migrate upstream during higher flows and downstream following spawning.

Traps are generally installed in mid-March, once winter flows have subsided and stabilized somewhat. In some years, spring rains occasionally raise flows enough to compromise trap operation. Stream flows usually drop substantially by late May or early June, so traps are usually removed at this time. In each of the monitored watersheds, the NPS I&M program montains a stream gage for measurement of average daily discharge. A Hobo-brand temperature logger is deployed and left in each trap box for the duration of operation.

2.2.3 Fish Handling

Mark-recapture methods were used to estimate trap efficiency and smolt population size using DARR (Darroch Analysis with Rank Reduction). Daily, no more than 30 smolts (or 50% of the catch that day) of coho smolts were anesthetized with carbon dioxide and marked with small but identifiable fin clips or dye on fins using a needleless injector. Marked smolts were released immediately at a predetermined site no more than 250 m above the trap site. Mark combinations were alternated weekly. All adults, parr, fry, and recaptured smolts were released immediately after measurement in low velocity areas below the trap. Daily, a random sub-sample of steelhead parr, coho and steelhead presmolts, coho and steelhead smolts, and steelhead residents are measured and weighed. This sub-sample is normally 10 of each species, however, if fish are anesthetized for mark-recapture purposes, they should also be measured.

2.2.4 Site Locations

Smolt traps should be located as far downstream as possible in the sampled watershed, preferably near the mouth of the stream, to provide the most accurate smolt productivity index for the watershed upstream of the trap. Channel character, accessibility, and protection are equally important. The site must have adequate vertical gradient to push water through the pipe as well as an area of low energy to house the trap box. The structure should be located in an area where equipment can be easily carried to the site. In addition, it is important that the trap be located in a place where vandalism is not likely. Figure 7 shows the locations of the smolt traps in Olema Creek, Redwood Creek, and Pine Gulch for the 2007 season.

The Olema mainstem trap is located on NPS lands approximately 400m upstream of the mouth. Due to high flow failure and the capture of California red-legged frog tadpoles and adults in the trap box during the 2005 and 2006 trapping season, the trap was relocated in 2007 approximately one kilometer upstream. NPS staff chose a trap location upstream of the previous location in an attempt to avoid major red-legged frog breeding areas.

On Redwood Creek, the trap is located at the most downstream end of the watershed, near the Muir Beach public parking area. This area is slated for restoration in 2009-2010, and the trapping will be continued.

On Pine Gulch Creek, the smolt trap has been located on private property (New Land Trucst) in order to minimize disturbance. In 1999, the NPS operated a trap downstream on public lands (New Lnd Trust). In 1999, the NPS operated a trap downstream on public lands and the trap was vanadalized, resulting in tke for more than a dozen smolts.

Figure 7. Location of smolt traps on SFAN streams in Marin County, CA.

2.2.5 Sampling Period

Past literature was reviewed to determine the appropriate start and ending points for the trapping season. In Waddell and Scott Creeks (Santa Cruz County), outmigration of coho smolts began in mid-March and peaked in mid-May (Shapovalov and Taft 1954). In Lagunitas Creek (Marin Co.), results from smolt trapping from 1983-1985 indicated that coho emigration began in early April and ended in late June (Bratovich and Kelley 1988). Steelhead emigration generally begins in early-March and ends by June (Bratovich and Kelley 1988). Based on our trapping experience, we have observed outmigration primarily in April and May, with the peak occurring in late April-early May.

Currently during the trapping season, mid March – May, the traps operate 24 hours per day, and are checked on a daily basis. This frequency was selected to balance excessive labor efforts with the need to prevent injury because of prolonged trap residence. When possible the trap was checked twice-daily to prevent incidental mortality of adult steelhead and steelhead fry. We have observed similar trends, with most movement into the traps occurring at night. Under high flow events, the trap is checked frequently during the day to remove accumulated debris within the trap and at the weir or the trap box is left open to allow safe passage for fish. If possible, traps are opened in anticipation of high flows to avoid potential or excess mortality.

In order to minimize impacts to newly emerged fry, the trap box is fitted with a ¼ inch mesh screen to allow smaller fish to pass through the box, and still catching smolts.

2.2.6 Smolt Trap Data Analysis

Information produced through this program includes weekly and daily totals of fish captured, including smolts, other age 1+ juveniles, and young of year. Weight-length relationships for smolts and other age 1+coho salmon and steelhead are reported. Mark/recapture methods are used to estimate trap efficiency.

Mark/recaptured data can also be analyzed using DARR (Darroch Analysis with Rank Reduction), a software application developed by Eric Bjorkstedt at the NMFS Southwest Fisheries Science Center (Bjorkstedt 2000). The software facilitates analysis of temporally stratified mark/recapture data based on methods developed by Darroch (1961).

Using the efficiency method to estimate population could result in overestimates of population. Estimates reported through this method would require the following assumptions: 1) there is no mortality of released fish; 2) there is no residualization or behavior change (far more probable in steelhead than coho); and 3) released fish are redistributed and have a constant probability of capture.

In addition, tissue and scale samples are collected from a subsample of fish moving through the smolt trap during each year. This will allow for further genetic analysis of central California coast salmonids, as well as age-length relationships and determination of smolt age for both coho and steelhead.

2.3 Juvenile Surveys

Monitoring juvenile salmonids during their freshwater residence phase provides information on overall population trends, particularly when combined with adult spawning data and smolt emigration data (Collins 2003), which are also part of our monitoring program. Sampling is most

effective during summer and fall base flow conditions, when water clarity is greatest and conditions are more conducive to observation and capture of juvenile salmonids and other stream fish.

Three primary activities are conducted in the watersheds including index reach monitoring, basinwide snorkel surveys, and General Systematic Sampling during the summer/fall sampling period. Complete field methods are documented in SOP 1 of the San Francisco Area Network Stream Aquatic Resource Monitoring Protocol (Ketcham et. al. 2005).

2.3.1 Rational for Sampling Design

Three monitoring efforts are conducted during the summer/fall season to document juvenile salmonids. Index reach monitoring provides density information on all fish species in these reaches, and is comparable to other local and regional watersheds. Index reaches monitored as part of this program include 7-12 years of monitoring data, and are considered a legacy dataset. Basinwide surveys are conducted on the mainstem reaches of Olema, Pine Gulch, and Redwood Creek. The implementation of a probabilistic sampling program, including annual habitat surveys and snorkel counts to estimate coho population began in 2001 for Pine Gulch Creek, 2003 for Olema Creek, and 2004 for Redwood Creek. In watersheds (mainly tributary systems) where snorkeling is not advisable due to limited water quality conditions, this program has implemented General Systematic Sampling to provide estimates of salmonid use within these intermittent stream systems.

Methods used for juvenile salmonid surveys are also conducive to monitoring other species of stream fish. Snorkeling, seining, and electrofishing allow for the sampling of most other aquatic vertebrate species, as well as larger invertebrates (e.g. crustaceans). Monitoring the species composition, population levels, and biomass of stream fish assemblages can indicate the health of the stream and riparian systems, which in turn reflects the condition of associated terrestrial ecosystems. In some cases, resident fish such as sculpin, which are dependent on the stream throughout their life cycle, may respond to changing habitat conditions more rapidly than salmonids.

2.3.2 Juvenile Survey Field Methods

Field methods for summer juvenile coho and steelhead monitoring are organized by survey type since a variety of surveys are utilized during the summer juvenile monitoring season. Although multiple surveys techniques may be deployed within the same sampling period, each survey type should be treated as a stand alone survey.

2.3.3 Index Reach Monitoring

Index reaches are sampled at SFAN parks during summer/fall base flow periods to assess fish abundance and distribution on the mainstem of Olema Creek, Redwood Creek, and Pine Gulch Creek. Under this technique, established stream reaches approximately 100 meters in length, have been surveyed annually since the mid- to late- 1990s.

Each index reach contains from two to ten contiguous habitat units, which are identified and sampled individually. Each habitat unit is isolated with block nets and sampled separately using standard multiple pass depletion electrofishing methods (Bohlin et al 1989). Where appropriate, snorkel surveys or seine hauls are used in conjunction with electrofishing. Index reach surveys include both fish sampling and detailed habitat assessments, including habitat unit size, substrate, in-stream shelter, and riparian condition.

Habitat measurements and assessments are made for the index reaches after fish sampling is completed. The length, average width and depth, substrate composition, and in-stream shelter complexity (Flosi et. al. 1998) are quantified in each habitat unit. Transects are set up across each habitat unit and depth and substrate type are recorded at points along the transects. In-stream shelter complexity values are estimated for pool and flatwater units. Additional habitat parameters including bank erosion, riparian cover, and woody debris are then determined for the index site as a whole. The habitat portion of index reach monitoring is completed the same day as fish sampling or very soon thereafter.

Index reach surveys provide baseline fish distribution information and abundance/density estimates. Measurements of individual fish weight and length are also used to generate biotic condition factors for salmonids in each watershed. Juvenile salmonid year class abundance varies depending on returns of adult spawners and environmental conditions. By comparing the baseline fish density estimates derived from consecutive survey years, the variations in year class abundance can be monitored. Because steelhead often spend in excess of one year in freshwater, annual surveys also may provide information on the overwintering success of different year classes.

2.3.4 Electrofishing/Handling

All captured fish are documented as part of the monitoring effort. To reduce fish handling impacts, a subsample of 10 fish per pass, per species is measured and weighed. Fish are kept in aerated holding buckets before and after handling, and allowed to recover fully before being released. Measured fish are sedated using carbon dioxide (Alka Seltzer ^{TM}), identified to species and age class, measured, and weighed. In some cases, fin clips or scale samples are also collected for age and/or genetic analysis. All other fish are identified to species, their occurrence counted, and transferred directly to the recovery buckets.

An electrofishing log is kept of all settings, pertinent environmental conditions, fish response, and total catch for each unit. All electrofishing information is reported annually in Section 10 Reports to NOAA Fisheries. Water quality parameters are measured and recorded.

For habitat units sampled by multiple pass electrofishing, maximum likelihood model, *Microfish* (VanDeventer and Platts 1989) is used to calculate fish population estimates and confidence intervals by species/age class. Total catch is used as the population estimate for species with poor multiple pass depletions or no captures after the first pass, and in units sampled with a single pass.

2.4 Basinwide Estimate Methods

Basinwide survey techniques, developed by Hankin and Reeves (Dollof et al 1993), provide a statistically accurate estimate of stream habitat or population of a particular fish species for a broad area or entire stream. Basinwide surveys involve a two stage sampling design using both snorkeling and electrofishing.

2.4.1 Habitat Surveys

Starting at the bottom of the coho survey area and working upstream, staff numbered, classified, measured the length, and estimated the average width of each habitat unit. Units are classified to level III using the CDFG classification system (Flosi et al 1998) as pool (scour pool, backwater pool, plunge pool, or mid-channel pool), flatwater, or riffle. Side channel and backwater units are

also measured. The width of each habitat unit was estimated visually. Every fifth pool unit was flagged for snorkeling and several measured widths were taken for the purpose of calibrating the estimated width. Index reach pools are also flagged for snorkeling.

All large woody debris (LWD), alive or dead, providing instream shelter during summer baseflow conditions are counted and recorded within each habitat unit. To qualify as LWD, individual logs must meet specific size requirements. Logs must be at least 2 m (6 ft.) in length and are tallied in the following diameter classes: 10-20 cm (4-8 in.), 20-50 cm (8-20 in.), and greater than 50 cm (>20 in.). Diameter is measured at the mid-point of the log. Stumps with their root structure intact that are less than 2 m long and at least 20 cm in diameter are tallied separately. These "rootwads" are very stable structures and can provide excellent juvenile fish habitat. Accumulations of more than 10 individual pieces of LWD constitute a large woody debris jam. Each jam is tallied separately. Pieces of wood that are between 5 and 10 cm in diameter are considered small woody debris (SWD). We do not be count individual pieces of SWD. Ten or more pieces of SWD are recorded as SWD jams.

2.4.2 Basinwide Snorkel Surveys

Project staff surveyed each of the previously determined pools with a single to triple pass snorkel count, using dive lights to search under vegetation, woody debris, and undercut banks. Only coho were counted but the presence of steelhead and non-salmonid fish was also noted.

The number of divers in the water varied from one to three, depending on the width and complexity of the unit. Strategies were used to divide the fish between the divers and filter them in such a way that the divers could be confident of their counts.

Typically, snorkeling is calibrated by followup electrofishing of randomly selected dive pools. Because heavy staff effort is invested in the index reach effort, we combined the surveys by using the index reaches for the electrofishing portion of the basinwide survey on Olema Creek, Redwood Creek, and Pine Gulch Creek. When possible a random subset of the snorkled pools were immediately resampled using the method of bounded counts (Murphy and Willis 1996) to provide an unbiased calibration method.

2.5 General Systematic Sample Design

In tributaries to Olema Creek (John West Fork, Giacomini Creek, and Quarry Gulch), as well as Cheda Creek and Bear Valley Creek, snorkeling is not advisable due to limited water quality conditions, and evaluation of index reach data from these sites are not representative of the watershed. In these watersheds, we conduct equiprobable general systematic sampling (GSS) using habitat surveys and electrofishing of systematically drawn pool units to estimate juvenile population and distribution. An equiprobable GSS design allows for broad spatial coverage and thus provide an accurate representation of fish populations in tributaries. Using this method, electrofished pools are systematically selected based on basinwide habitat surveys, rather than clumped together as in the case of index reaches.

2.5.1 Juvenile Survey Sample Dates

Index reaches and basinwide surveys for each stream are sampled during the same general time of year on an annual basis. Tributaries are sampled earlier in the season prior to the intermittent stream flow conditions typical in the late summer and fall. In these intermittent reaches, sampling later in the summer would add greater stress on the individual fish sampled through this program. Table 1 provides the sample dates for the 2007 summer/fall stream fish surveys.

Table 1. Index reach/basinwide survey sample dates, 2007.

Watershed	Stream	No. Index Reaches	In-stream Sample Dates
Olema	John West Fork	GSS	June 22 – June 26, 2007
Lagunitas	Cheda Creek	GSS	June 26- June 27, 2007
Olema	Giacomini Creek	GSS	June 28, 2007
Olema	Quarry Gulch	GSS	June 28, 2007
Olema	Mainstem	8	July 6 – July 26, 2007
Pine Gulch	Mainstem	8	July 31 – August 16, 2007
Redwood	Mainstem	7	August 30 – September 27, 2007
Redwood	Fern Creek	Snorkel	September 24, 2007
Lagunitas	Bear Valley Creek	GSS	October 9 – October 10, 2007

3 - Results

3.1 WY 2007 Rainfall Totals – Bear Valley Headquarters

The data collected at the Bear Valley rain gage shows that the 2007 water year was drier than the average year when compared to the historic data set collected since 1965 (Table 2). The total rainfall for 2007 was 27.69 inches where as the average for the last 42 years was 38.83 inches. The January 2007 total of 1.09 inches was less than 20% of the January average, which can be a critical time for spawning activity of coho salmon.

Figure 8 shows the annual rainfall totals for the last 42 water years. The minimum annual rainfall occurred in 1977 with only 15.03 inches of rainfall and the maximum occurred in 1983 with almost 79.84 inches. The graph depicts the large variation that can occur from year to year in this region. Annual rainfall data are not available for 1969 and 1971.

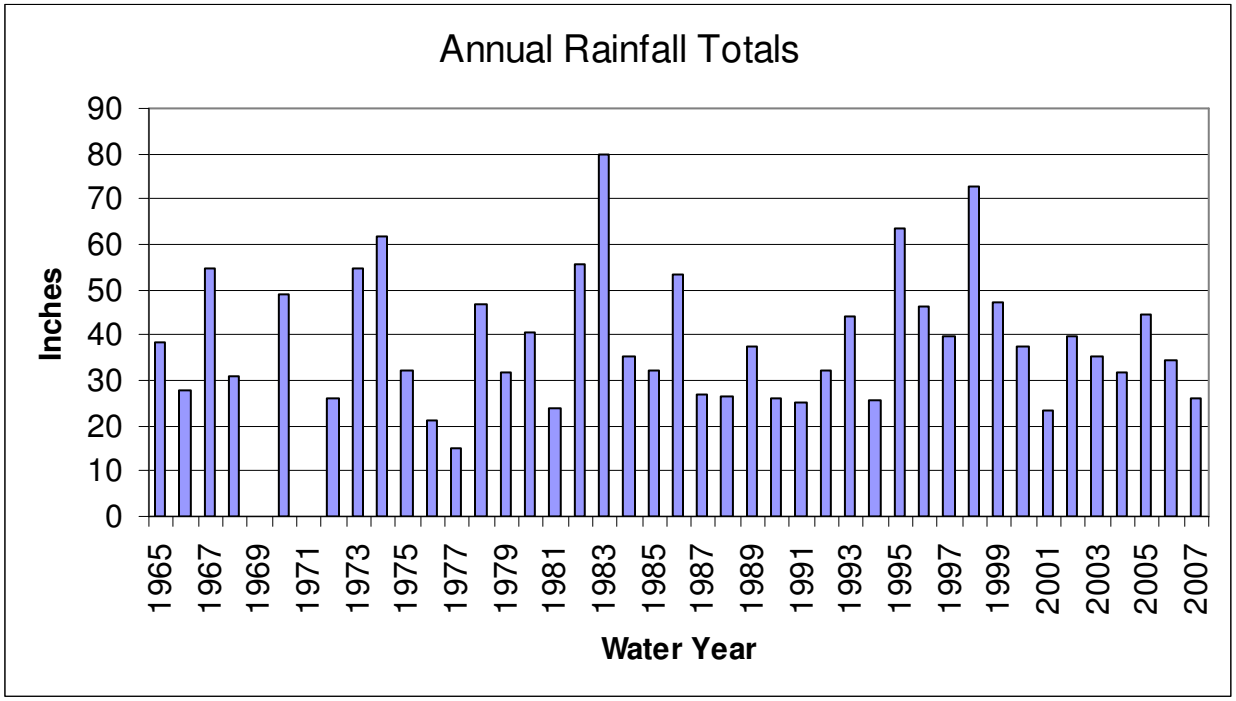


Figure 8. Annual rainfall totals taken at Bear Valley rain gage from 1965- 2007, missing data from 1969 and 1971.

Table 2. Average monthly rainfall at Bear Valley, 1965-2006 compared with 2007.

	Total	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June
Average	38.83	1.95	5.35	7.36	8.21	6.5	5.48	2.43	1.13	0.23
Min	15.03	0.00	0.61	0.01	0.4	0.47	0.24	0	0	0
Max	79.84	5.74	18.2	22.99	22.39	24.68	24.28	6.6	6.35	1.86
2007	27.69	0.82	5.54	6.43	1.09	9.93	0.06	2.64	1.18	0

3.2 Olema Creek Escapement

Spawner surveys were initiated on Olema Creek in 1997. For more detailed results on individual surveys performed during the 2006-2007 spawner season please see the 2006-2007 Annual Escapement Report (Del Real 2007).Escapement monitoring information on Olema Creek shows that run timing is highly dependent on the rainfall-runoff conditions within the watershed. Unlike Lagunitas Creek, Olema Creek is an unregulated stream. This makes Olema Creek far more vulnerable to the variable environmental conditions that limit flows in the winter season. Adult coho salmon runs within the CCCESU are compressed into a very short window, with upstream migration coinciding with brief peak winter discharges, typically peaking in January (Weitkamp et.al. 1995). Freshwater residence time is short (typically less than 2 weeks), though the NPS program has documented some individuals spending up to 20 days in freshwater under ideal conditions.

Olema Creek watershed spawner survey information includes data collected on 11.6 kilometers of the mainstem of Olema Creek, primarily reaches 2-6, and John West Fork, a tributary to Olema (see Figure 3). In addition, spawner surveys were conducted on Quarry Gulch, Boundary Gulch, Horse Camp Creek, and Giacomini Creek. For analysis, escapement results within these drainages are treated separately.

3.2.1 Survey Timing and Environmental Conditions

Our monitoring efforts have shown some years where flows necessary to allow entry into the watershed did not occur until mid-January. In those years, fish were observed, stacked in the estuary waiting for Olema Creek attraction flows. In other years, rains in November have resulted in flows that would allow coho access to the watershed. Even when the early entry opportunity has occurred in November, few coho have been observed. For the most part, peak spawning activity within Olema Creek is between mid-December and mid-January. Typically the peak count will follow a large flow event, encouraging fish that were waiting at the mouth of the watershed to enter and spawn. Table 3 shows the approximate entry and spawning window monitored for coho salmon between spawner years (SY) 1997-1998 and SY 2006-2007.

Table 3. Coho salmon run timing, average total rainfall by month, and Olema Creek Peak Live plus Cumulative Dead (PLD), total carcasses and redds documented in the surveys for spawner years 1997-1998 through 2006-2007 within the Olema Creek mainstem. Shaded area represents the time of year in which adult coho were observed within Olema Creek.

Spawner year	Run Timing				Total Monthly Rainfall (in)				Olema Creek PLD			
	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Survey Area (km)	PLD Index	Total Carcass Counts	Total New Redds
1997-1998					10.32	3.47	16.49	24.68	13.4	88	39	126
1998-1999					7.48	2.21	7.66	15.61	11.6	42	13	42
1999-2000					5.2	0.99	7.15	12.77	7.2	9	9	10
2000-2001					1.54	1.31	6.45	8.07	11.6	103	65	86
2001-2002					9.81	15.03	5.08	3.55	11.6	90	28	58
2002-2003					3.3	17.33	3.75	2.34	11.6	20	17	5
2003-2004					2.71	12.14	5.13	7.68	11.6	138	34	88
2004-2005					0.65	10.13	4.85	5.33	11.6	184	63	92
2005-2006					3.27	19.9	7.94	4.76	11.6	12	11	2
2006-2007					5.54	6.43	1.09	9.93	11.6	80	27	66

Conditions where Olema Creek run timing was far different than that observed in Lagunitas Creek occurred in 1999-2000 and 2000-2001, where Olema entry flow was delayed by 2 months, and in 2002-2003 and 2003-2004, where Olema entry flows were delayed by one month (Table 3). Surveys indicated that coho did indeed wait to enter the watershed, and that once in the stream, spawning occurred almost immediately. This behavior has raised an important question regarding how populations maintain themselves in a watershed with regulated and unregulated channels. The escapement and timing within the unregulated Olema Creek watershed may be affected negatively by outside influences.

Under State Water Resources Control Board Order 95-17, the Marin Municipal Water District is required to release winter attraction flows (>25 cfs for three days) through Lagunitas Creek prior to December 1 each year. Such releases in a low-flow year could attract fish that would otherwise move up Olema Creek. In addition, the estuary at the mouth of Olema Creek is highly constrained by levees associated with Sir Francis Drake Blvd and the Giacomini Dairy. A project to remove several levees to restore the natural estuarine and flood plain processes began in the fall of 2007. For fish that do remain near the mouth of Olema Creek for an attraction flow, the shallow, exposed pools may make adult salmon susceptible to both temperature effects and predation. Each of these factors may play into the escapement in years where natural rainfall runoff conditions are temporally distinct from the winter reservoir releases.

For the 2006-2007 season, six surveys were conducted in Olema Creek between 21 November 2006 and 16 February 2007. The mean interval between surveys was fourteen days. Seven day rainfall totals during Julian week ranged from a low of 0 during Julian weeks 53 and 5 and a high of 5.54 during Julian week 6. Average water clarity at the time of surveys ranged from 52cm to 100cm. The onset of rainfall and subsequent higher flows appeared to be related to live fish observations (Figure 9).

Historic observations show a bi-modal return, with high returns in Julian week 51 and 3, correlating with a mid December and mid-January return. Surveys are constrained in most years

by the holiday season, which is possible for the lower historic numbers in Julian week 52 and 53. Figure 10 shows that 40% of the returning coho during the 2006-2007 spawning season were observed during Julian week 51 (December 17th to December 23rd). Based on the past 10 years of data this spawning peak fell within the average spawning time for the Olema Creek watershed. A second peak was also observed during Julian week 53

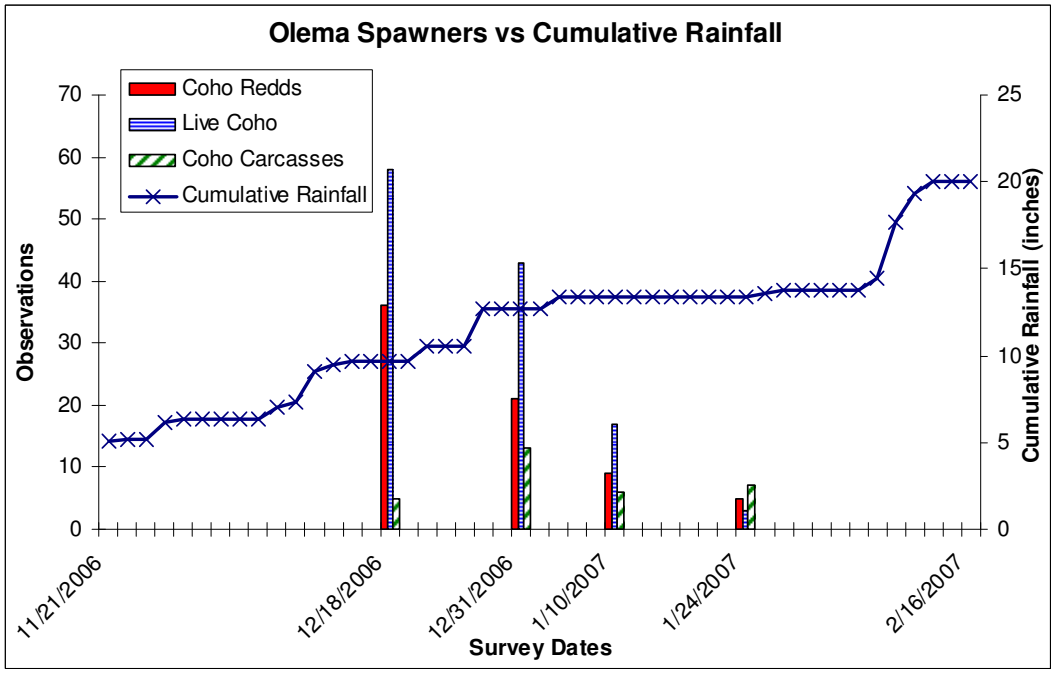


Figure 9. Representation of rainfall totals and coho adult escapement survey results on Olema Creek Mainstem, including live fish, carcasses, and redds, observed during surveys in 2006-2007.

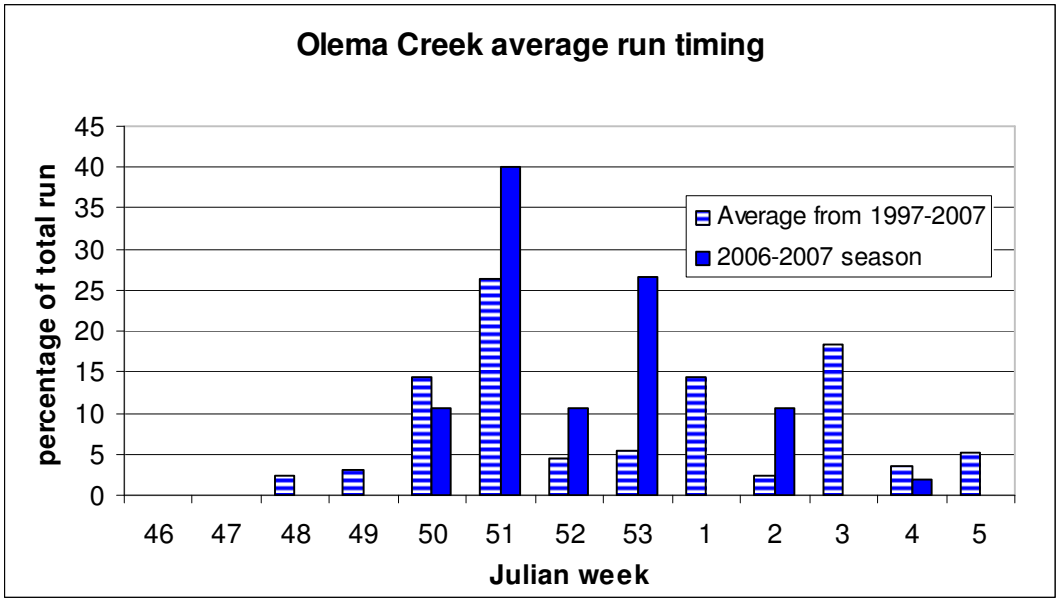


Figure 10. Olema Creek, adult Coho run timing, based on number of live fish observed, 1997-2007.

Seven surveys were conducted on 2 kilometers in John West Fork (reaches 1-2) between 11 December 2006 and 12 February 2007. The mean interval between surveys was nine days. Seven day rainfall totals during Julian week ranged from a low of 0 during Julian weeks 53 and 5 and a high of 5.54 during Julian week 6. Average water clarity at the time of surveys ranged from 30cm to 100cm. The onset of rainfall and subsequent higher flows appeared to be related to live fish observations.

In addition to John West Fork, four other tributaries to the Olema mainstem were surveyed between December and February. The timing of tributary surveys generally proceeded the mainstem surveys and were dependent on flow. Sections of Quarry Gulch, Giacomini Gulch, Horse Camp Gulch, and Boundary Gulch were also surveyed.

3.2.2 Live Fish (Coho)

Spawner surveys of the Olema Creek mainstem were performed between November 21, 2006 and February 16, 2007. While live fish observations do not represent the total number of spawning adults, a total of 121 live adult coho were observed between November and February. In the Olema mainstem, two peak spawning activities were observed on December 18 with 58 live coho and on January 10 with 17 live coho observed.

John West Fork Creek, a tributary to Olema Creek, was first surveyed on December 11. A total of 38 live adults were documented on John West Fork, between December and February. Two peaks were observed on John West Fork with the first peak of 10 coho observed on December 14 and the second peak of 17 fish occurring on December 29.

Four additional tributaries to the Olema mainstem (Quarry Gulch, Boundary Gulch, Horse Camp Creek, and Giacomini Creek) were surveyed between December and January. Of the four tributaries, a total of three live coho spawners were observed in Giacomini Creek on December 14.

3.2.3 Live Fish (Steelhead)

Although adult steelhead are not a focus of this study, observations of steelhead were recorded in the same fashion as live adult coho. Because of their behavior, actual live adult steelhead counts are assumed to be much higher than the observed counts. The peak steelhead count on Olema Creek was observed on February 16, 2007 with a count of 18 live adult steelhead. Steelhead were observed on spawner surveys from December 31 to February 16 representing the highest total count of steelhead for all monitored years in Olema Creek. In addition, live adult steelhead were observed incidentally into late May on the mainstem of Olema Creek while operating a downstream migrant trap. No adult steelhead were observed during surveys performed on John West Fork Creek.

3.2.4 Carcasses (Coho)

A total of 27 carcasses were found on the mainstem of Olema Creek during the 2006-2007 season. Two marked carcasses were recaptured during the December 31 surveys; thirteen days after the first peak number of live fish was observed. The greatest number of carcasses was found between stream kilometers 10 and 13 in survey reach 5. The carcass sex ratio was 22% male, 60% female and 11% unknown. Based on the distribution of fish sizes, it appeared that jacks (precocious two-year old males) composed 7% of the recovered coho. The mean fork length of male (excluding jacks) and female carcasses was 69cm and 65cm respectively. The results of previous spawner surveys in the Olema Creek watershed suggested that jacks were typically less than 50cm fork length. The mean length of males less than 50 cm fork length during the 2006-2007 surveys was 39cm.

Of the five tributaries surveyed during the 2006-2007 season, a total of 5 carcasses were found on John West Fork. No marked carcasses were recovered. All of the carcasses were discovered between December 14 and January 8. On John West Fork the carcass sex ratio was 40% male, 20% female, and 40% unknown.

3.2.5 Carcasses (Steelhead)

Only one steelhead carcasses was recovered while performing spawner surveys on Olema Creek. It was recovered on January 16 and identified as a jack male with a fork length of 35cm. No steelhead carcasses were observed while surveying Olema Creek tributaries.

3.2.6 Redds (Coho)

Redds are the best means of spatially representing spawning densities within the watershed. Within Olema Creek, monitoring efforts have allowed spatial representations of redd density per 100 meter sections since 1997-1998. Accumulation of this data show high use areas for spawning within the Olema and John West Fork watersheds.

A total of 66 confirmed redds were observed in the mainstem of Olema Creek during the 2006-2007 season. Redd construction was concentrated in survey reaches 5 and 6 where 67% of the redds were observed. Most mainstem redds were documented during the December 18 and December 31 surveys. The total density of redds in the 11.6 km mainstem survey section was 5.7 redds/km. The mean surface area of all coho redds was 5.4m^2.

For the 2006-2007 spawner season the number of redds found in each stream kilometer was very similar to the average of the last 10 years of observations from 1997-2006 (Figure 11). The majority of redds were found in kilometer 15 and 13 which is the most utilized spawning grounds when we look at the 10 year average and the 2006-2007 season.

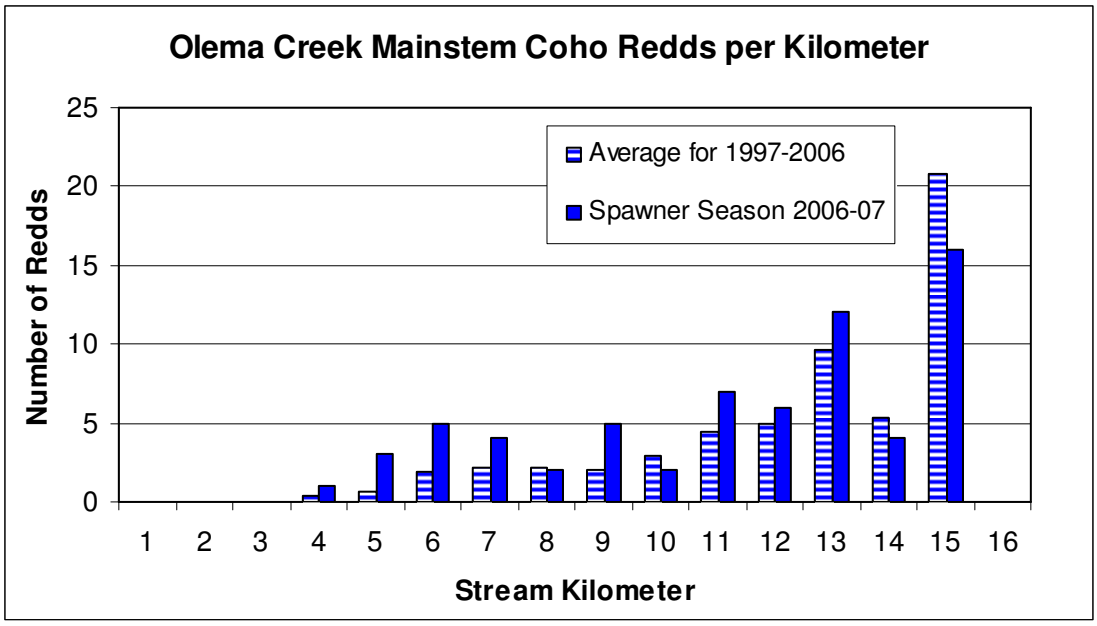


Figure 11. Olema Creek mainstem, Coho redds per stream kilometer for 2006-2007 compared with the average of 1997-2006.

A total of 29 definite coho redds were observed in John West Fork during the 2006-2007 spawner season. Redd construction was concentrated upstream of the State Route 1 culvert in John West Fork representing 76%. Coho redds were constructed between December 11 and January 8. The density of redds in the 2.0 km of streambed surveyed in John West Fork was 14.5 redds/km. Observers made comments of the streambed that could not be positively identified as coho redds but were marked as possible redds instead. Only one questionable redd was observed**.** Figure 12 shows a map representing coho spawning density for the 2006-2007 season.

For the 2006-2007 season the highest density of spawning occurred in stream kilometers 1 and 1.1. The other bulk in spawning activity occurred between stream kilometer 0.1 and 0.5. Results of monitoring over the past 10 years, indicated that redds have been distributed throughout the John West Fork, with highest densities between the mouth and km 0.5, and km 0.9 to 1.2.(Figure 12). In these reaches, the spawning density ranges from 10-20 redds per kilometer.

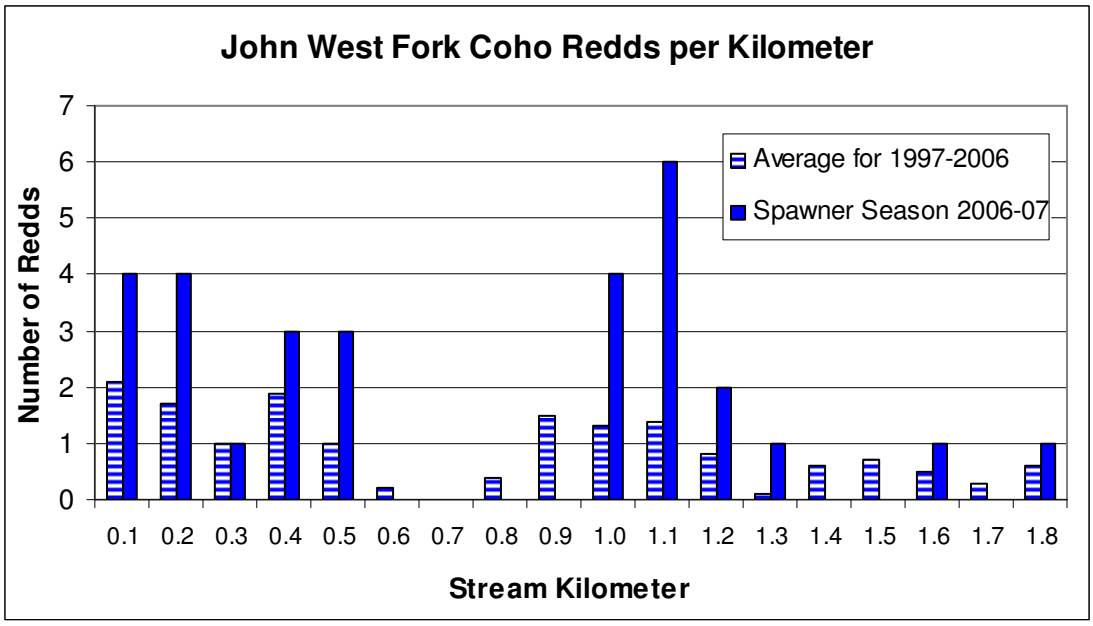


Figure 12. John West Fork, Coho redds per kilometer for 2006-2007 compared with the average from 1997-2006.

3.2.7 Redds (Steelhead)

A total of 17 definite steelhead redds and one potential redd were observed on Olema Creek between January 10 and February 16. Steelhead redd observations were concentrated in reaches 2 (stream km 3 through 6) and 6 (stream km 13 through 15) of Olema Creek representing 66% of confirmed steelhead redds. Figure 13 shows the location of steelhead redds in Olema creek mainstem observed in the 2006-2007 season and the average of locations from 2000-2006.

The density of redds in the 11.6km mainstem section surveyed was 1.5 redds/km. The mean surface area of the steelhead redds was 2.2m^2. There were no steelhead redds identified in John West Fork during the 2006-2007 spawner surveys due to low water levels. The number and distribution of steelhead redds observed during the 2006-2007 spawning season was much higher then the average from the last six years of survey data (Figure 13).

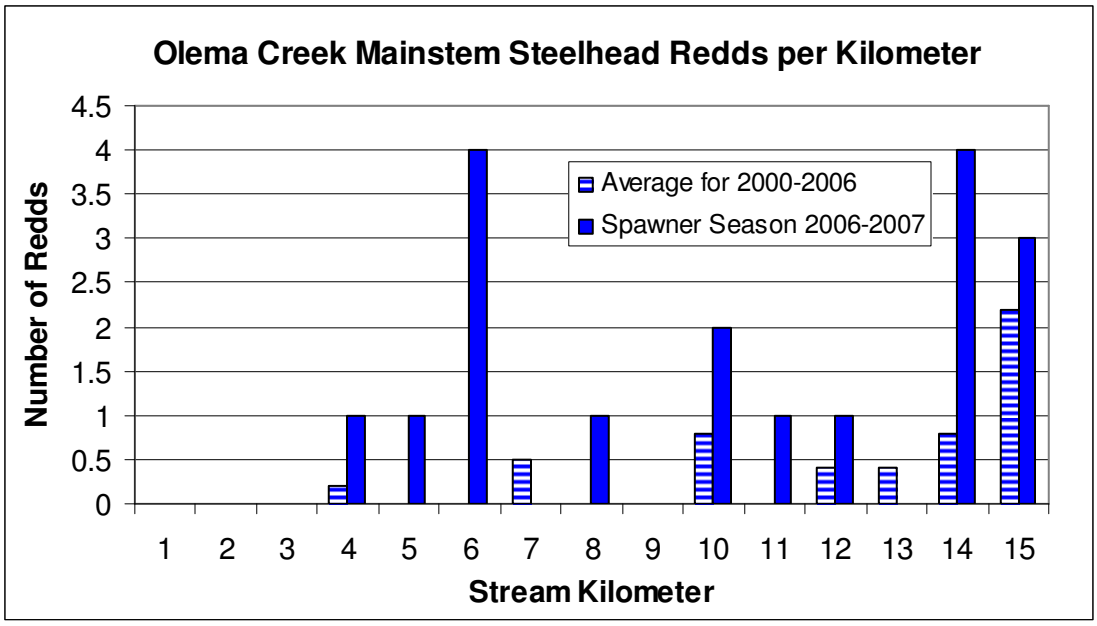


Figure 13. Olema creek mainstem, steelhead redds per kilometer for 2006-2007 compared with the average from 2000-2006.

3.2.8 Olema Creek Escapement Estimates (Area Under the Curve)

Area Under the Curve (AUC) estimates were generated for live fish on Olema Creek mainstem and John West Fork during 2006-2007 spawner surveys. When possible residence time (RT) was estimated based on observations of female coho holding on redds with the RT period equaling the previous storm event at time of entrance to the last observation of an individual female coho holding on a redd location. Observations of individual female coho salmon at the same redd location from one survey week to the next were considered to be the same fish. Observer efficiency was also estimated when possible based on average water clarity over the duration of the spawner season for each creek. When RT and OE values could not be determined AUC estimates were calculated based on values from published coho spawner studies. Eight studies were reviewed and had RT values ranging from eight to seventeen days. The most frequently reported values were eleven and thirteen days. Two of the eight studies reported OE values between 69 and 76 percent (Solazzi et al.1984, Johnston et al. 1987). To consider a wider range of observer efficiencies, AUC estimates were calculated for OE values between 50 and 100 percent.

Population estimates in the Olema Creek section ranged from 80 to 170 coho at 100% OE and 160 to 341 fish at 50% OE (Table 4). Estimates from the most commonly reported OE (70-80%) and RT (11-13 days) values ranged from 131 to 177 fish in Olema Creek.
Based on our survey OE and estimated RT, AUC estimates for coho salmon in Olema Creek range from 114 to 150.

Population estimates in the John West Fork survey section ranged from 16 to 34 coho at 100% OE and 32 to 68 fish at 50% OE (Table 5). Based on the most commonly reported OE and estimated RT, AUC estimates for coho salmon in John West Fork ranged from 26 to 35.

Table 4. Area Under the Curve (AUC) population estimates for coho salmon adults in reaches 2-6 of Olema Creek during 2006-2007.

Residence Time (days)	Observer Efficiency					
	100%	90%	80%[f]	70%[c]	60%	50%
8[a]	170	189	213	243	284	341
9[b]	151	168	189	216	252	303
10[c]	136	151	170	195	227	273
11[d,e,f]	124	138	155	177	207	248
12	114	126	142	162	189	227
13[a,e,f,g]	105	116	131	150	175	210
14[g]	97	108	122	139	162	195
15[a]	91	101	114	130	151	182
16	85	95	106	122	142	170
17[a]	80	89	100	115	134	160

[a]Irvine et al. (1992)
[b]van der Berghe and Gross (1986)
[c]Flint (1984)
[d]Beidler and Nickelson (1980)
[e]Johnston et al. (1987): 69% observer efficiency
[f]Crone and Bond (1976)
[g]Koski (1966)
[h]Solazzi et al. (1984): 76% observer efficiency

3.2.9 Olema Creek Escapement Estimates (Peak Live plus Cumulative Dead)

Due to the three-month spawning period and the variability in residence time on the spawning grounds, the same live fish are often double counted during repeated surveys. An index derived from adding the peak number of live fish observed during a single survey to the number of carcasses recovered prior to that date provides a minimum spawner escapement estimate. The 2006-2007 peak live plus cumulative dead (PLD) index was 80 adult coho on the Olema Creek mainstem. A PLD index of 28 adult coho was calculated for John West Fork.

Olema Creek Watershed Escapment History: Escapement estimates for adults in Olema Creek have been made using both the Peak Live plus cumulative Dead (PLD) and Area Under the Curve (AUC) method. In years where persistent high flows resulted in a low number of surveys, both methods likely under-represented the true escapement number due to low OE.

Annual escapement estimates for Olema Creek show a range of 9-184 using the PLD index. Estimates using the AUC method are much higher with estimates reaching beyond 300 adults in some years. The Olema Creek escapement estimates represent 3-40% of the total escapement estimated for the Lagunitas Creek watershed (see Table 14).

Table 5. Area Under the Curve (AUC) population estimates for coho salmon adults in John West Fork during 2006-2007.

Residence Time (days)	Observer Efficiency					
	100%	90%	80%[f]	70%[c]	60%	50%
8[a]	34	38	42	48	56	68
9[b]	30	33	38	43	50	60
10[c]	27	30	34	39	45	54
11[d,e,f]	25	27	31	35	41	49
12	23	25	28	32	38	45
13[a,e,f,g]	21	23	26	30	35	42
14[g]	19	21	24	28	32	39
15[a]	18	20	23	26	30	36
16	17	19	21	24	28	34
17[a]	16	18	20	23	27	32

[a]Irvine et al. (1992)
[b]van der Berghe and Gross (1986)
[c]Flint (1984)
[d]Beidler and Nickelson (1980)
[e]Johnston et al. (1987): 69% observer efficiency
[f]Crone and Bond (1976)
[g]Koski (1966)
[h]Solazzi et al. (1984): 76% observer efficiency

3.2.10 PLD Index Results

The PLD dataset for adult escapement within Olema Creek includes 13 years of survey information. It should be noted that prior to SY 1997-1998, redds and carcasses were not consistently counted. Olema Creek mainstem (Table 6) and the John West Fork tributary (Table 7) are reported separately. PLD estimates have ranged from 9 to 184 for the mainstem and 8-86 for JWF. The John West Fork tributary has been the focus of extensive restoration and monitoring, and is often used as the proxy of conditions in the mainstem. In the SY 1999-2000 and SY 2002-2003, PLD estimates and live fish observations on the two kilometer survey area of JWF exceeded those of the 13 kilometer mainstem. The results of SY 1999-2000, SY 2002-2003, and SY 2005-2006 are not considered representative of actual mainstem escapement due to poor survey conditions in the Olema mainstem during these years.

Table 6. Coho salmon spawning survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for the Olema Creek mainstem, 1994-2007.

Year	No. Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds	Source
1994-1995	3	13.4	53	1	9	Tomales Bay Association (TBA)
1995-1996	2	13.4	106	37	N/A	Manning 1999
1996-1997	2	15.6	174	16	N/A	Manning 1999
1997-1998	8	13.4	88	39	126	Manning 1999
1998-1999	6	11.6	42[a]	13	42	NPS-PRNS
1999-2000	2	7.2	9[b]	9	10	NPS-PRNS
2000-2001	4	11.6	103	65	86	NPS-PRNS
2001-2002	4	11.6	90[c]	28	58	NPS-PRNS
2002-2003	4	11.6	20[b]	17	5	NPS-PRNS
2003-2004	6	11.6	138[d]	34	88	NPS-PRNS
2004-2005	6	11.6	184[d]	63	92	NPS-PRNS
2005-2006	3	11.6	12[b]	11	2	NPS-PRNS
2006-2007	6	11.6	80[d]	27	66	NPS-PRNS

[a]Includes two peaks, 7 weeks apart.
[b]Surveys missed peak numbers.
[c]Includes two peaks, 4 weeks apart
[d]Includes two peaks, 3 weeks apart
N/A = not available.

Table 7. Coho salmon spawning survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for the John West Fork of Olema Creek, 1995-2007.

Year	No. Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds	Source
1995-1996	N/A	<1.0	8[a]	N/A	N/A	NPS-PRNS
1996-1997	N/A	N/A	N/A	N/A	N/A	NPS-PRNS
1997-1998	5	1.3	12	0	7	NPS-PRNS
1998-1999	2	1.2	9	0	1	NPS-PRNS
1999-2000	3	1.1	18[b]	0	7	NPS-PRNS
2000-2001	4	1.9	58	30	48	NPS-PRNS
2001-2002	6	1.9	20	5	31	NPS-PRNS
2002-2003	7	1.3	27[c]	0	12	NPS-PRNS
2003-2004	6	2.4	41	7	21	NPS-PRNS
2004-2005	7	2.4	86[d]	12	45	NPS-PRNS
2005-2006	7	2.4	8	0	4	NPS-PRNS
2006-2007	7	2.4	28[e]	5	29	NPS-PRNS

[a]Includes live fish only, no carcass data.
[b]Surveys missed peak numbers.
[c]Includes two peaks, 4 weeks apart
[d]Includes two peaks, 3 weeks apart
[e]Includes two peaks, 2 weeks apart
N/A = not available.

Table 8. Coho salmon spawning survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for all of the tributaries of the Olema Creek watershed excluding the John West Fork. These tributaries include Quarry Gulch and Giacomini Creek, Horse Camp Creek, and Boundary Gulch, 1997-2007.

Year	No. Creeks Surveys	Total Live	Total Carcasses	Total New Redds	Source
1997-1998	6	4	1	3	NPS-PRNS
1998-1999	0	0	0	0	NPS-PRNS
1999-2000	2	0	0	0	NPS-PRNS
2000-2001	4	0	0	0	NPS-PRNS
2001-2002	4	1	0	0	NPS-PRNS
2002-2003	0	0	0	0	NPS-PRNS
2003-2004	2	0	0	1	NPS-PRNS
2004-2005	6	2	3	3	NPS-PRNS
2005-2006	4	3	0	3	NPS-PRNS
2006-2007	3	3	0	0	NPS-PRNS

Overall trends in coho spawning based on observed redds in the Olema watershed are shown in Figure 14. The three year classes are represented as primary colors (yellow-1, blue-2, and red-3) to show relationships between spawning runs. Year class 2 shows a rapid increasing trend in spawning over the last three generations. Year class 1 has remained relatively constant over the past three generations and may be the most consistent cohort with an average PLD of 93 adult spawners (22.5 SD). Year class 3 continues to struggle with a dramatic decline between 2002-2003 and 2005-2006. Each creek is shown in a different pattern to illustrate the location of spawning activity from year to year as well as with in year classes.

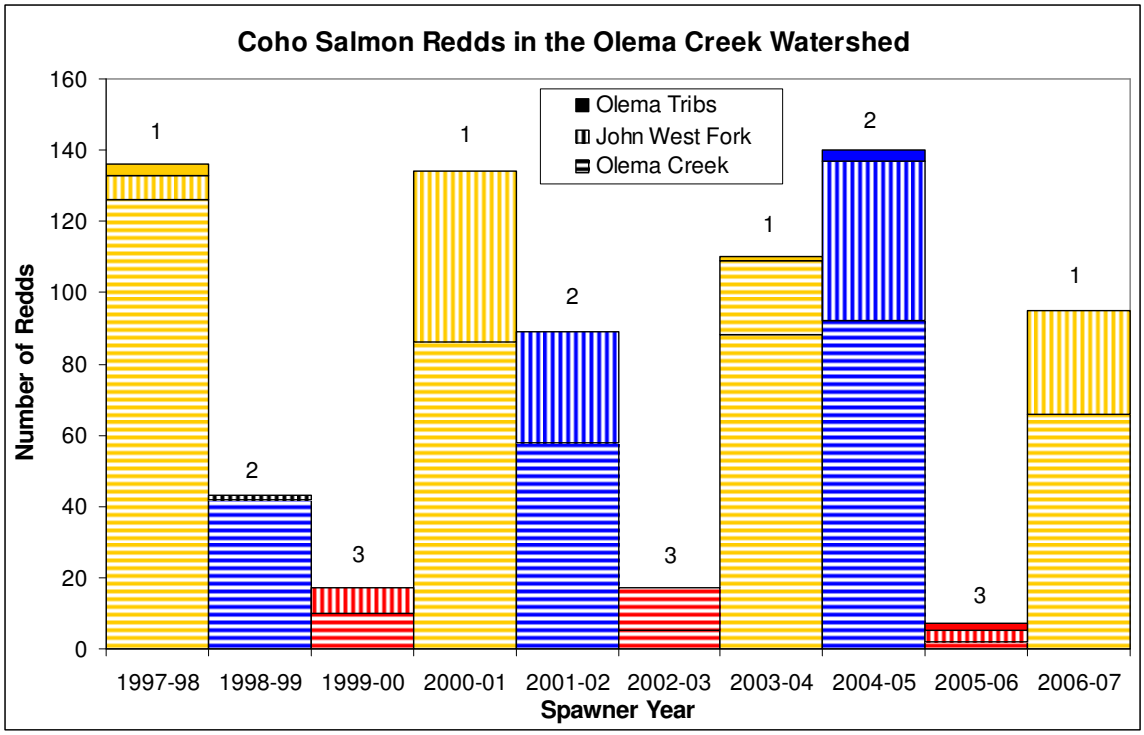


Figure 14. Coho Salmon redd results by year class for winter 1997-1998 through winter 2006-2007. Year classes are designated by color (Year Class 1 shown in yellow, Year Class 2 shown in blue, Year Class 3 shown in red) and creeks are designated by pattern (Olema Creek in horizontal lines, John West Fork in vertical, and other Olema tributaries in a solid color).

Overall trends in coho spawning based on redd observations in the Olema Creek mainstem are shown in Figure 15. The three year classes are represented as primary colors (yellow-1, blue-2, and red-3) to show relationships between spawning runs. Year class 1 had shown a steady increase in population size since 1994-1995 until this last generation 2006-2007 is which a major reduction was observed. Year class 2 shows a rapidly increasing trend in spawning since spawner year 1998-1999. Year class 3 continues to struggle with a dramatic decline beginning with spawner year 1999-2000 and has declined further in the last generation.

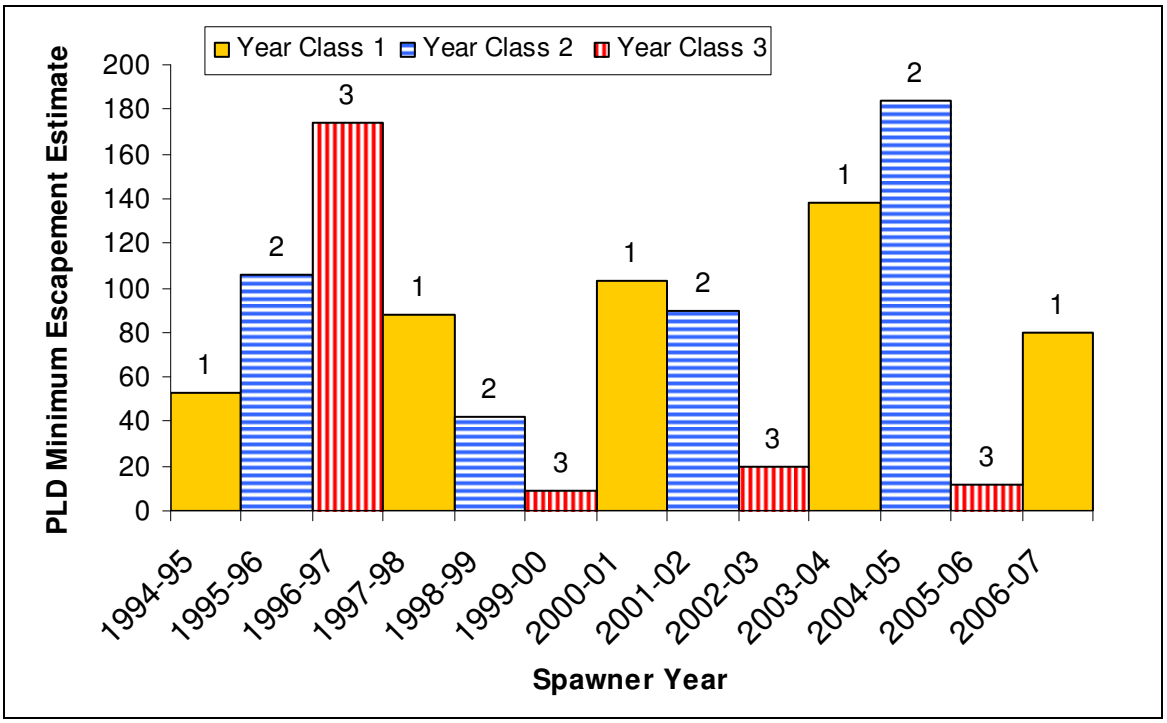


Figure 15. Olema Creek coho salmon Peak Live plus Cumulative Dead (PLD) Index escapement results winter 1994-1995 through winter 2006-2007.

Overall trends in coho spawning based on redd observations in John West Fork are shown in Figure 16. The three year classes are represented as primary colors (yellow-1, blue-2, and red-3) to show relationships between spawning runs. Year class 1 peaked in spawner year 2000-2001 declining in the last two year classes. Year class 2 shows an increasing trend in spawning over the last four generations with a substantial increase during the 2004-2005 spawner year. Year class 3 continues to struggle but has reestablished itself since the zero count during the 1996-1997 spawner year.

3.2.11 AUC Escapement Estimate

The PLD index is assumed to be a minimum count of fish within a watershed, as it is based on actual observations. The NPS has also used the AUC method to estimate adult escapement within Olema Creek (Table 9) and the John West Fork tributary (Table 10). This method requires more consistent surveys and allows for an estimate of survey quality (observer efficiency) and the residence time of fish within the watershed. This method will tend to overestimate fish numbers where there are multiple peaks of fish or if there is a large interval between surveys. Only live fish are calculated using this technique.

AUC estimates in the Olema Creek section ranged from 80 to 170 coho at 100% OE and 160 to 341 fish at 50% OE (Table 9). Based on our survey OE and estimated RT, AUC estimates for coho salmon in Olema Creek range from 114 to 150. Population estimates in the John West Fork survey section ranged from 16 to 34 coho at 100% OE and 32 to 68 fish at 50% OE (Table 10). AUC estimates for coho salmon in John West Fork ranged from 32 to 45.

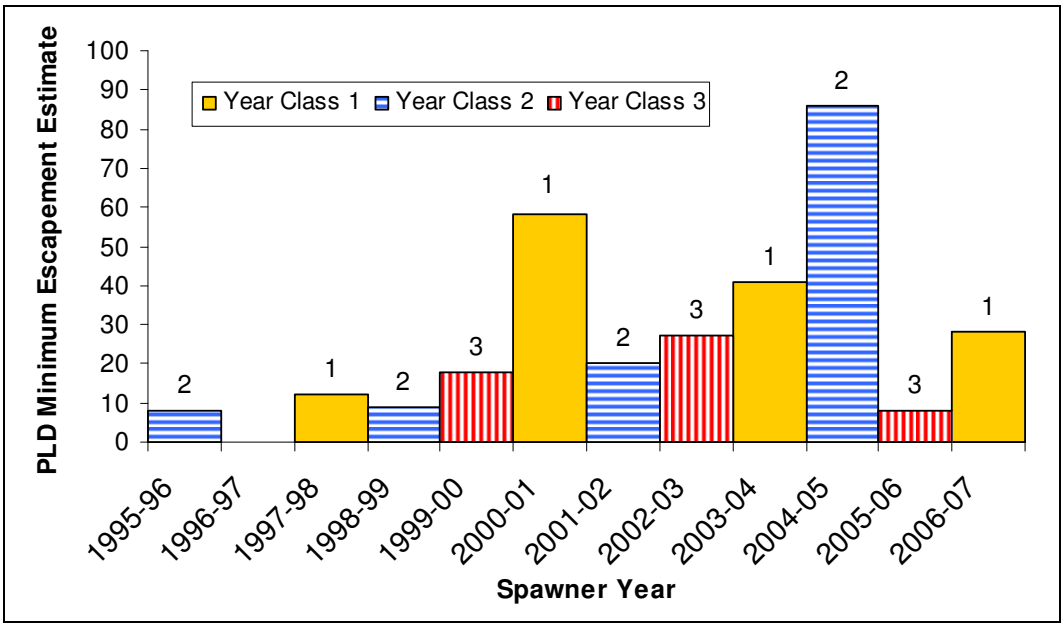


Figure 16. John West Fork Creek coho salmon Peak Live plus Cumulative Dead (PLD) Index Escapement results winter 1995-1996 through winter 2006-2007.

Table 9. Coho salmon spawning survey Area Under the Curve (AUC) Peak Live plus Cumulative Dead (PLD) estimates for Olema Creek, 1997-1998 through 2006-2007. AUC estimates are given for 50%, 70-80%, and 100% Observer Efficiency (OE) and a Residence Time (RT) of 8-17 days.

Year	No. Surveys	Date of Entry	Mean Survey Interval (days)	Survey Reaches	Survey Area (km)	AUC Range 100% OE RT 8-17 Days	AUC Range 50% OE RT 8-17 Days	AUC Range 70-80% OE RT 11-13 Days	OLM Mainstem PLD
1997-1998	7	15 Nov 97	7.9	2-4	4.5	56-118	112-236	91-123	88
1998-1999	5	19 Nov 98	12.1	2-6	11.6	25-53	49-105	57-77	42
1999-2000	2	18 Jan 00	N/A			N/A	N/A	N/A	9
2000-2001	2	10 Jan 01	7.3	2-6	11.6	75-159	149-317	122-165	103
2001-2002	3	24 Nov 01	12.3	2-6	11.6	105-224	210-447	172-232	90
2002-2003	2	13 Dec 02	N/A			N/A	N/A	N/A	20
2003-2004	4	14 Dec 03	11.8	2-6	11.6	138-293	275-585	225-304	138
2004-2005	6	15 Dec 04	10.8	2-6	11.6	149-316	298-632	243-328	184
2005-2006	3	01 Dec 05	16.6	2-6	11.6	N/A	N/A	N/A	12
2006-2007	6	09 Dec 06	14.3	2-6	11.6	80-170	160-341	114-150	80

N/A – Survey data for mainstem was not adequate to develop AUC estimate.

Table 10. Coho salmon spawning survey Area Under the Curve (AUC) Peak Live plus Cumulative Dead (PLD) estimates for John West Fork, 1997-1998 through 2006-2007. AUC estimates are given for 50%, 70-80%, and 100% Observer Efficiency (OE) and a Residence Time (RT) of 8-17 days.

Year	No. Surveys	Date of Entry	Mean Survey Interval (days)	Reaches	Survey Area (km)	AUC Range 100% OE RT 8-17 Days	AUC Range 50% OE RT 8-17 Days	AUC Range 80% OE RT 11-13 Days	John West Fork PLD
1997-1998	N/A	15 Nov 97	7.9					-	12
1998-1999	N/A	19 Nov 98	12.1					-	9
1999-2000	3	18 Jan 00	4.7	1-2	1.1	7-15	14-30	12-16	18
2000-2001	4	10 Jan 01	9.4	1-2	1.9	42-90	85-180	69-94	58
2001-2002	6	24 Nov 01	7.4	1-2	1.9	25-53	50-107	41-55	20
2002-2003	6	13 Dec 02	6.9	1-2	1.3	14-30	28-61	23-31	27
2003-2004	4	14 Dec 03	9.6	1-3	2.4	30-64	60-129	49-67	41
2004-2005	7	10 Dec 04	8.8	1-2	1.8	60-127	120-255	98-132	86
2005-2006	7	01 Dec 05	7.7	1-2	2.4	8-18	17-36	14-19	8
2006-2007	7	09 Dec 06	9	1-2	2.4	16-34	32-68	32-45	28

N/A – Survey data for John West Fork was not adequate to develop AUC estimate.

3.2.12 Live Fish and Carcass biotics

Information on live fish and carcasses are collected during each field survey. Information on sex ratios for live fish and carcasses are reported in Table 11. While live fish lengths are estimated, carcasses are handled to definitively determine sex, spawn success, fork length (FL), and for collection of a genetic sample. The results of carcass measurements show that males are generally between 56-70 cm, with females averaging 50-67 cm and jacks averaging from 37-49 cm.

3.2.13 Olema Creek Watershed Summary

The emerging picture from 13 winters of coho spawner surveys on Olema Creek (see Figure 15) reveals the presence of one stable year class (year class 1), one currently strong but variable year class (year class 2) and one variable year class that is currently in low numbers (year class 3). Previously, year class 3 was probably a much stronger year class, with a PLD index of 180 during the 1996-1997 spawning run. However, the subsequent cohort likely suffered high mortality during the last large-scale El Nino Southern Oscillation (ENSO) event in 1997-1998. This event caused high flows during the winter of 1997-1998 which may have resulted in low over winter survival for the juvenile coho. Results of adult escapement and summer juvenile density monitoring indicate that the over wintering year class during the height of El Nino was the most heavily impacted and marks the shift of that cohort to the weakest year class. Although low spawner counts for the last three runs of this year class may be due in part to poor survey conditions, juvenile density observations support the notion that this became, and now remains the weakest year class. Also of concern is the decline of year class 2 observations during the winter of 2006-2007. This year class has been strong for the last two generations, but the last return results show reduced escapement which is likely the result of decreased ocean survival related to limited upwelling conditions in spring 2005.

On John West Fork Creek, 10 winters of coho spawning surveys (Figure 16) has revealed dramatic increase in coho spawners above the State Route 1 culvert (MP 22.67) since the

completion of the culvert modification to improve fish passage. In spawner year 2006-2007, there was an increase in redd construction but a decrease in the PLD index for year class 1 which may be due in part to poor survey conditions. In the 1999-2000 and 2002-2003 spawning years, JWF counts exceeded mainstem results, likely due in part to lower flows and better survey conditions on the tributary.

Table 11. Sex ratios and size measured by fork length (FL) of live coho and carcasses within Olema Creek. Standard deviation is refered to as SD.

Year	Month	Live Coho		Carcasses			
		#	%	#	%	Mean FL	FL SD
1997-1998	M	71	30%	16	47%	63.9 (n=15)	5.1
	F	95	40%	12	35%	59.1 (n=11)	3.1
	J	42	18%	5	15%	45.4 (n=5)	4.3
	Unk	29	12%	1	3%		
	All	237	100%	34	100%		
1998-1999	M	11	21%	4	31%	64.0 (n=2)	1.4
	F	25	47%	4	31%	61.0 (n=4)	3.4
	J	7	13%	3	23%	45.7 (n=3)	2.1
	Unk	10	19%	2	15%		
	All	53	100%	13	100%		
1999-2000	M	1	50%	2	22%	65.0 (n=1)	
	F	1	50%	6	67%	58.3 (n=6)	8.2
	J	0	0%	1	11%		
	Unk	0	0%	0	0%		
	All	2	100%	9	100%		
2000-2001	M	42	34%	22	34%	66.3 (n=22)	6.4
	F	61	50%	35	54%	65.4 (n=35)	4.7
	J	17	14%	8	12%	44.9 (n=8)	2.0
	Unk	3	2%	0	0%		
	All	123	100%	65	100%		
2001-2002	M	38	40%	8	30%	72.5 (n=6)	2.7
	F	46	48%	12	44%	66.7 (n=6)	6.3
	J	6	6%	1	4%	45.0 (n=1)	
	Unk	5	5%	6	22%		
	All	95	100%	27	100%		
2002-2003	M	0	0%	7	41%	68.8 (n=4)	6.3
	F	2	67%	0	0%		
	J	1	33%	2	12%	37.5 (n=2)	3.5
	Unk	0	0%	8	47%	57.5 (n=4)	14.4
	All	3	100%	17	100%		
2003-2004	M	37	26%	7	21%	74.3 (n=4)	1.5
	F	68	48%	11	32%	66.3 (n=10)	6.3
	J	31	22%	6	18%	45.2 (n=6)	2.0
	Unk	5	4%	10	29%	60.0 (n=4)	12.2
	All	141	100%	34	100%		
2004-2005	M	72	27%	24	38%	68.7 (n=14)	6.1
	F	114	42%	25	40%	65.7 (n=20)	3.3
	J	72	14%	1	1%	47.0 (n=1)	
	Unk	46	17%	13	21%	59.0 (n=4)	11.5
	All	269	100%	63	100%		
2005-2006	M	1	33%	3	27%	57.0 (n=1)	
	F	1	33%	4	36%	58.7 (n=3)	7.2
	J	1	33%	2	18%	40.0 (n=2)	7.1
	Unk	0		2	18%		
	All	3	99%	11	99%		
2006-2007	M	43	36%	6	22%	69.0 (n=6)	3.5
	F	71	59%	16	60%	65.3 (n=15)	3.8
	J	4	3%	2	7%	39.0 (n=2)	1.4
	Unk	3	2%	3	11%		
	All	121	100%	27	100%		

3.3 Cheda Creek Escapement

Spawner surveys were initiated on Cheda Creek in 1998. For more detailed results on individual surveys performed during the 2006-2007 spawner season please see the 2006-2007 Annual Escapement Report (Del Real 2007).Cheda Creek is a small but important tributary of the Lagunitas Creek watershed and provides critical habitat for coho salmon (*O. kisutch)* and steelhead trout (*O. mykiss*). Cheda Creek spawner survey information includes data collected on 1.3 kilometers distributed between reaches 1-2 (see Figure 4). A total of 7 definite coho redds were identified distributed throughout the Cheda Creek spawner survey reaches.

3.3.1 Survey Timing and Environmental Conditions

Three surveys were conducted in Cheda Creek between 11 December 2006 and 29 December 2006 (Table 12). The mean interval between surveys was six days. Seven day rainfall totals during Julian week ranged from a low of 0.84 during Julian week 51 and a high of 2.86 during Julian week 50. Average water clarity at the time of surveys ranged from 45cm to 80cm.

Table 12. Seven day total rainfall per Julian week, average water clarity, and the number of coho redds, coho carcasses, and live coho observed in 2006-2007 on Cheda Creek.

Julian Week	Survey Date	Survey Reaches	Calendar Day	7 Day Rainfall During Julian Week (in)	Average Survey Water Clarity (cm)	Coho Redds	Coho Carcass	Live Coho
49	9 Dec 06			0.96				
50	11 Dec 06	1-2	345	2.86	80	0	0	0
(50)	14 Dec 06	1-2	348	(2.86)	45	0	0	0
51				0.84				
52	29 Dec 06	1-2	363	2.28	60	7	1	5
53				0				

Reach 1: Confluence with Lagunitas Creek to 0.8 km upstream.
Reach 2: Upstream extent of the fish passage restoration site at 0.8 km upstream to 1.3 km upstream

3.3.2 Live Fish (Coho)

While live fish observations do not represent the total number of spawning adults, a total of 5 live coho adults were observed during December. The sex ratio from live fish observed on Cheda Creek was 20% male and 80% female. The 2006-2007 peak live plus cumulative dead (PLD) index was 6 on Cheda Creek and includes coho counts from December 29.

3.3.3 Live Fish (Steelhead)

No live adult steelhead or steelhead spawning activity was observed during the 2006-2007 spawner surveys.

3.3.4 Carcasses (Coho)

One male coho carcass with a fork length of 70cm was found on Cheda Creek during the 2006-2007 season.

3.3.5 Redds (Coho)

A total of 7 confirmed redds were observed in Cheda Creek during the 2006-2007 season. Redd construction was distributed between reaches 1-2. All of the redds were observed during the survey on December 29. The total density of redds in the 1.3km survey section was 5.4 redds/km.

3.3.6 Cheda Creek Watershed Escapement History

The dataset for adult escapement within Cheda Creek includes nine years of survey information and has documented the return of coho to the small tributary stream of Lagunitas Creek (Table 13). Due to its small size and presence in the Lagunitas system, Cheda Creek spawner patterns are directly connected to those observed in the mainstem Lagunitas Creek. Our observations of Cheda Creek are intended to determine how a small downstream tributary is used by spawners before and after restoration.

The PLD index ranges from zero adults for the first three survey years to 17 adults observed in SY 2004-2005. The first observed returning year class (SY 2001-2002) appears to be coming back strong with both live adult observations and redd observations. The presence of spawning activity above the fish passage structure constructed in 2000 is a promising sign of recovery and documentation of the projects success. Seven redds were observed in the 2006-2007 spawner year, the highest count recorded since monitoring began in 1998.

Table 13. Coho salmon spawning survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for Cheda Creek.

Year	No. Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds	Source
1998-1999	2	N/A	0	0	0	NPS-PRNS
1999-2000	1	N/A	0	0	0	NPS-PRNS
2000-2001	2	1.4	0	0	0	NPS-PRNS
2001-2002	5	1.2	4	0	3	NPS-PRNS
2002-2003	3	1.2	2	1	1	NPS-PRNS
2003-2004	3	1.2	1	0	6	NPS-PRNS
2004-2005	5	1.3	17[a]	1	6	NPS-PRNS
2005-2006	4	1.3	1	1	2	NPS-PRNS
2006-2007	3	1.3	5	1	7	NPS-PRNS

[a]Includes two peaks, 3 weeks apart.
N/A-Survey area not defined

3.3.7 Lagunitas Creek Watershed Escapement History

The PLD index data have not been consistently gathered for all creeks in the project area and can vary in quality depending on the number of surveys conducted and other factors. Data on the number of new redds provides a good overview of recent spawning activity in PRNS watersheds (Table 14). This data indicate the high annual variability in coho spawning activity and the relative importance of Olema Creek to spawning in the Lagunitas Creek drainage. A summary table of redd density within the Lagunitas Creek watershed is provided as Table A10 – in Appendix A.

Table 14. Total coho redds in Lagunitas Creek Watershed, 1995-2007 (MMWD & PRNS)

Year	Lagunitas Creek Mainstem	San Geronimo Creek (Mainstem+Tribs)	Devil's Gulch (+ Cheda)	Olema Creek (Mainstem+Tribs)	Total New Redds	Olema Creek Redd Proportion
1995-1996	70	6	10	N/A	86	N/A
1996-1997	98	115	42	N/A	255	N/A
1997-1998	80	107 + 14	46	126 + 7	380	35%
1998-1999	92	46 + 14	31	42 + 1	226	19%

1999-2000	139	58 + 3	3	10 + 7	220	8%
2000-2001	119	56 + 18	11	86 + 48	338	40%
2001-2002	79	102 + 43	59 + 3	58 + 31	375	24%
2002-2003	71	39 + 22	24 + 2	5 + 12	175	10%
2003-2004	124	139 + 66	48 + 6	88 + 21	492	22%
2004-2005	120	140 + 18	112 + 6	92 + 45	633	22%
2005-2006	53	48+56	33+2	2+4	198	3%
2006-2007	128	117+38	55+7	66+29	440	22%

N/A = not available.

Overall trends in coho spawning based on observed redds in the Lagunitas Creek watershed are shown in Figure 17. The three year classes are represented as primary colors (yellow-1, blue-2, and red-3) to show relationships between spawning runs. Year class 2 shows an increasing trend in spawning over the last three generations which was observed throughout the Lagunitas watershed. Year class 1 has remained relatively constant. Year class 3 has shown a decline in the Lagunitas watershed over the past three generations. However in Devil's Gulch there has been an increase in spawning over the past three generations, a pattern that has not been observed in any of the other creeks in the watershed or region.

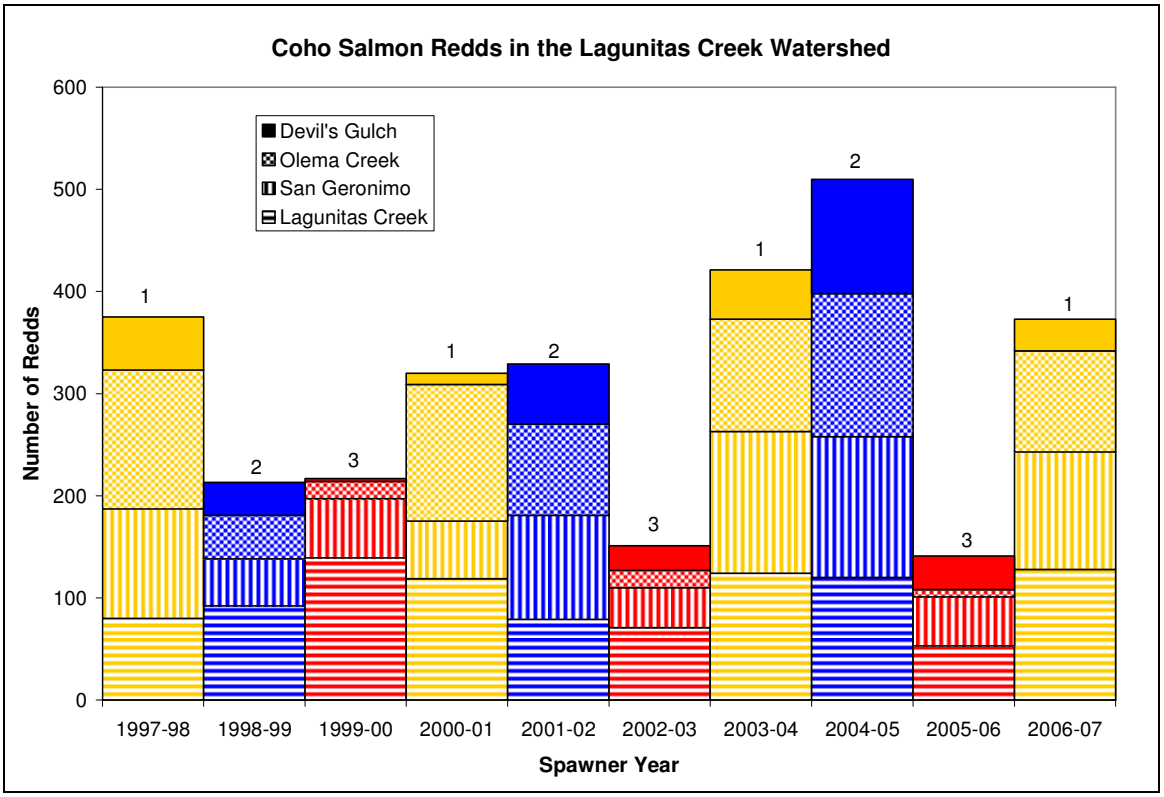


Figure 17. Coho Salmon redd results by year class winter 1997-1998 through winter 2006-2007. Year classes are designated by color (Year Class 1 shown in yellow, Year Class 2 shown in blue, Year Class 3 shown in red) and creeks are designated by pattern (Lagunitas Creek Mainstem in horizontal lines, San Geronimo Creek in vertical lines, Olema Creek in checkered, and Devil's Gulch in a solid color).

The contribution of the Lagunitas Creek mainstem to overall spawning activity in the drainage is indicated by data collected by MMWD since 1982 (Table 15) (MMWD 2003, MMWD 2005).

Coho spawner counts and redd data show that most of the spawning activity takes place on Lagunitas Creek tributaries. Spawning on the mainstem takes place largely in Samuel P. Taylor State Park, upstream of PRNS-administered grazing lands.

Devil's Gulch has the longest period of spawner survey records for the Lagunitas Creek watershed (Table 16). CDFG biologist Eric Gerstung and warden Al Giddings noted live coho and steelhead observations from 1948 to 1977. Consultants for MMWD conducted surveys from 1982-1984 and 1995-1997. PRNS expanded the sampling area further upstream in 1996-1997. Prior to 1982-83, no more than two surveys were conducted in a single season and carcasses and redd data were not consistently collected. During a single survey in 1948, 174 coho and steelhead were counted in a 2.6 km reach. Between 1957-1958 and 1976-1977, peak counts of live coho ranged between 70 and 130 fish. Coho numbers had dropped by the 1990s, with PLD index values between 1995-1996 and 2002-2003 ranging from 10 to 87 fish. Surveys in 2004-2005 exceeded counts even back to 1948. The total PLD index of 207 spawning coho is calculated from two observed peaks 25 days apart. In addition, the 112 redds counted during the same season in the watershed far exceeds any counts in the last decade.

Table 15. Coho salmon spawning survey data for Lagunitas Creek Mainstem, 1982-2007. Data includes total redds observed, total carcasses observed, and Peak Live plus Cumulative Dead (PLD) Index estimates.

Year	No. Surveys	PLD Index	Total Carcasses	Total New Redds	Source
1982-1983	6	N/A	N/A	65	Bratovich & Kelly 1988
1983-1984	6	N/A	N/A	26	Bratovich & Kelly 1988
1991-1992	1	N/A	N/A	34	Wise 1992
1995-1996	10	129[a]	N/A	70	Trihey & Assoc. 1996
1996-1997	8	170[a]	23	98	Trihey & Assoc. 1997
1997-1998	10	46	27	80	MMWD
1998-1999	8	56[b]	6	92	MMWD
1999-2000	14	371[b]	37	139	MMWD
2000-2001	14	181[b]	18	119	MMWD
2001-2002	15	214[b]	25	79	MMWD
2002-2003	13	283[b]	18	71	MMWD
2003-2004	17	270[b]	23	124	MMWD
2004-2005	17	448[b]	37	120	MMWD
2005-2006	20	152	4	53	MMWD
2006-2007	19	166	44	128	MMWD

[a]Peak live fish counts only, no cumulative dead.
[b]Corrected live fish observations reported by MMWD, may include repeat sightings of same fish
N/A= not available.
MMWD = Marin Municipal Water District data

Table 16. Coho salmon spawning survey data for Devil's Gulch, 1948-2007. Data includes total redds observed, total carcasses observed, and Peak Live plus Cumulative Dead (PLD) Index estimates.

Year	No. Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds	Source
1948	1	2.6	174[a]	N/A	N/A	Gerstung & Giddings
1957-1958	2	2.4	100[b]	N/A	74	Gerstung & Giddings
1960-1961	1	2.6	77[b]	N/A	N/A	Gerstung & Giddings
1961-1962	1	2.6	70[b]	N/A	N/A	Gerstung & Giddings
1964-1965	1	1.6	91	76	N/A	Gerstung & Giddings
1965-1966	2	2.6	130[b]	N/A	N/A	Gerstung & Giddings
1976-1977	1	2.4	100	90	N/A	Gerstung & Giddings
1982-1983	6	2.4	NA	N/A	23	Bratovich & Kelly 1988
1983-1984	6	2.4	NA	N/A	11	Bratovich & Kelly 1988
1995-1996	6	2.4	19[b]	N/A	10	Trihey & Assoc. 1996
1996-1997	3	3.2	47	20	42	Trihey & Assoc. 1997; PRNS
1997-1998	8	3.2	27	7	45	PRNS
1998-1999	6	3.2	26	6	30	PRNS
1999-2000	2	3.2	10	1	3	PRNS
2000-2001	4	3.2	14	2	11	MMWD
2001-2002	11	3.2	46	12	59	MMWD
2002-2003	5	3.6	87[c]	1	24	MMWD
2003-2004	10	3.6	76[d]	12	48	MMWD
2004-2005	14	3.6	207[e]	32	112	MMWD
2005-2006	9	3.6	64	7	33	MMWD
2006-2007	10	3.6	73	3	55	MMWD

[a]Peak live fish count includes both coho and steelhead, does not include carcass data.
[b]Peak live fish counts without accumulated carcass data.
[c]two peaks, 27 days apart
[d]two peaks, 24 days apart
[e]two peaks, 25 days apart
N/A = not available.
MMWD = Marin Municipal Water District data; PRNS = Point Reyes National Seashore data

3.4 Redwood Creek Escapement

Spawner surveys were initiated on Redwood Creek in 1998. For more detailed results on individual surveys performed during the 2006-2007 spawner season please see the 2006-2007 Annual Escapement Report (Del Real 2007). Survey Timing and Environmental Conditions: Review of the nine years of coho salmon escapement monitoring information on Redwood Creek indicates that run timing is highly dependent on the rainfall-runoff condition within the watershed (Table 17). Redwood Creek is an unregulated stream with variable environmental conditions that limit flows in the winter season. During most years access to Redwood Creek depends on the breaching of a sand bar at it's confluence with the Pacific Ocean also known as Big Lagoon. Adult coho salmon upstream migration coincides with brief peak winter discharges, typically peaking in January (Weitkamp et.al. 1995). Freshwater residence time is short (typically less than 2 weeks), though the NPS program has documented some individuals spending up to 20 days in the freshwater under ideal conditions.

Table 17. Coho salmon run timing, average daily discharge by month, and Redwood Creek Peak Live plus Cumulative Dead (PLD), total carcasses and redds documented in the surveys for spawner years 1998-1999 through 2006-2007 within the Redwood Creek mainstem.

Spawner	Run Timing				Total Monthly Rainfall (in)				Redwood Creek PLD			
Year (SY)	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds
1998-1999					3.28	1.49	5.27	8.47	9.4	39	10	55
1999-2000					2.72	0.59	5.95	0.00	8.4	10	1	7
2000-2001					0.00	0.00	4.39	6.07	9.4	49	11	34
2001-2002					0.00	0.00	0.83	3.56	9.4	94	48	29
2002-2003					2.18	13.04	1.23	1.83	9.4	24	3	4
2003-2004					2.62	3.45	7.21	6.38	9.4	67	25	43
2004-2005					0.80	7.59	3.66	3.09	9.4	182	70	74
2005-2006					2.19	12.57	0.00	3.48	9.4	27	5	12
2006-2007					2.58	4.27	0.63	3.63	9.4	28	6	21

On November 12, 2006, a series of storm events increased stream flows to a level that breached the sand bar at Big Lagoon and allowed access for returning adult coho to the Redwood Creek watershed. Our first spawner survey was completed on Redwood Creek on November 20. A few adult coho were observed in Reach 1 during our first round of surveys representing the earliest return of coho since monitoring began in 1997. However spawning activity was not observed until after the next storm system began on December 8th.

Redwood Creek watershed spawner survey information includes data collected on 9.4 kilometers of the mainstem of Redwood Creek, reaches 1-3, and two major tributaries, Fern Creek and Kent Creek (see Figure 5). The Redwood Creek mainstem reaches 1 thru 3 were consistently sampled during each survey. Both Kent Creek and Fern Creek were surveyed when volunteer and staff turnout was high enough to cover both the mainstem and tributary reaches. Tributary reaches were surveyed on the same day as the mainstem reaches to eliminate the possibility of double counting. Nine surveys were conducted in Redwood Creek between 20 November 2006 and 15 February 2007. The mean interval between surveys was ten days. Average water clarity at the time of surveys ranged from 48cm to 100cm. The onset of rainfall and subsequent higher flows appeared to be related to live fish observations and spawning activity (Figure 18).

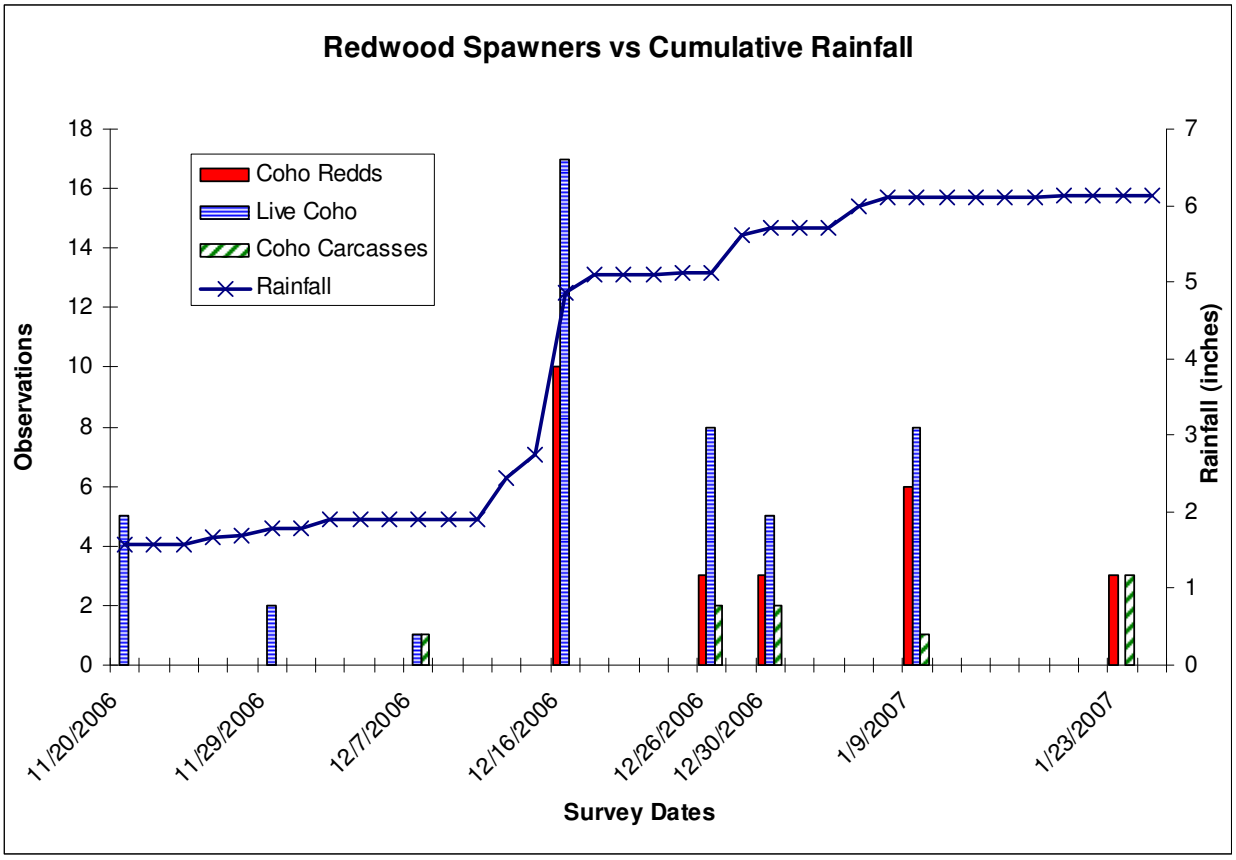


Figure 18. Representation of rainfall totals and adult escapement survey results on Redwood Creek Watershed, including live fish, carcasses, and redds, observed during surveys in 2006-2007.

The majority of coho observed during the 2006-2007 spawning season were observed during Julian week 50 (December 10th – December 16th). Based on the past 10 years of data this spawning peak fell within the average spawning time for the Olema Creek Watershed. Figure 19 shows during the 2006-2007 season three peaks in live adults observations occured during Julian weeks 50, 52 and 2.

3.4.1 Live Fish (Coho)

While live fish observations do not represent the total number of spawning adults, a total of 44 live coho adults were observed between November and February in the Redwood Creek mainstem. In addition, there was a total of 1 live adult coho located in Fern Creek on December 16.

The total density of spawners during the peak of the run was 2 fish/km. Most live fish (52% of the total count) were observed in survey reach two, between stream kilometers 4 through 6. The sex ratio from live fish observations on the mainstem was 32% male, 59% female, and 9% unknown.

3.4.2 Live Fish (Steelhead)

Although adult steelhead were not a focus of this study, observations of steelhead were recorded in the same fashion as live adult coho. Actual live adult steelhead counts are assumed to be much higher than the observed counts. Steelhead were identified on spawner surveys conducted on January 9 and February 15. The peak steelhead count in Redwood Creek was observed on February 15, 2007 with 8 live adult steelhead. Most live fish (75% of the total count) were observed in survey reach two. In addition, 6 live adult steelhead were located in the upper reaches of Fern Creek, a tributary to Redwood Creek, on February 15, 2007 where typically no adult salmonids are detected. Although no formal surveys were conducted, live adult steelhead were observed into late March on the mainstem of Redwood Creek.

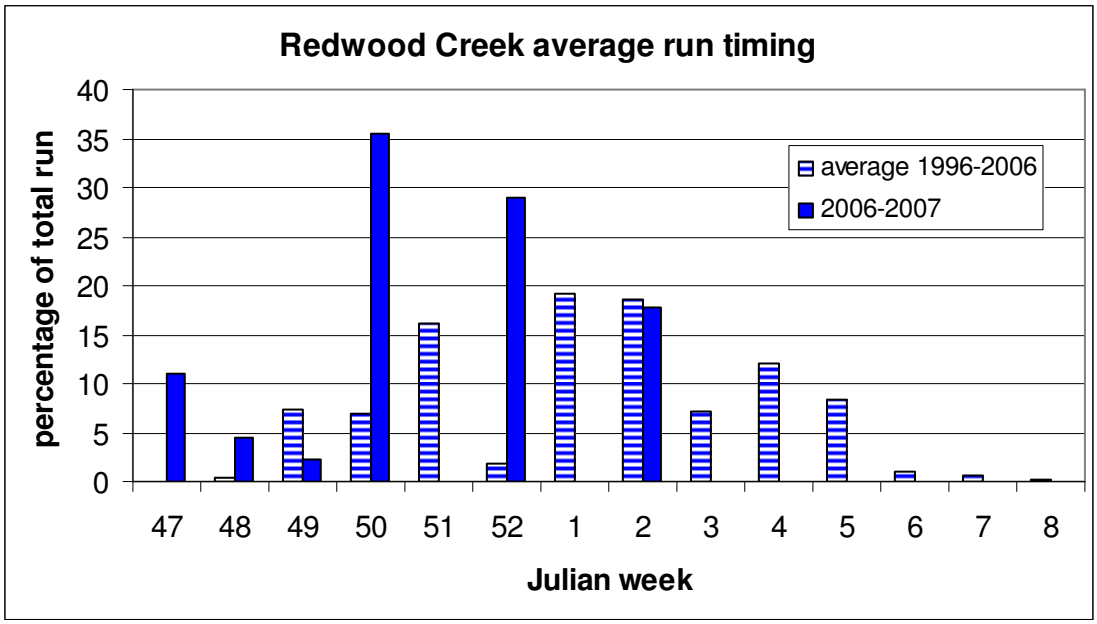


Figure 19. Redwood Creek, adult Coho run timing based on number of live adults observed.

3.4.3 Carcasses (Coho)

A total of 6 carcasses were found on the mainstem of Redwood Creek during the 2006-2007 season. Two marked carcasses were recaptured during subsequent surveys. Carcasses were recovered between December 26 and January 23. The carcass sex ratio was 66% female and 17% unknown. Based on the distribution of fish sizes, it appeared that jacks (precocious two-year old males) composed 17% of the recovered coho. The mean fork length of jack males during the 2006-2007 surveys was 44cm. No carcasses were located within Fern Creek or Kent Creek.

3.4.4 Carcasses (Steelhead)

No steelhead carcasses were observed during surveys within the Redwood Creek watershed.

3.4.5 Redds (Coho)

A total of 21 confirmed redds were observed in the mainstem of Redwood Creek during the 2006-2007 season. Redd construction was concentrated in survey reach 2 where 57% of the redds were observed. Most mainstem redds were constructed between December 16 and January 23. The total density of redds in the 7.4 km mainstem survey section was 3 redds/km. Figure 20

shows the location of redds for the 2006-2007 season compared with the average locations for the last 10 years of survey data. The figure shows the location and quantity of spawning activity for the 2006-2007 season to be very similar to the average from 1997-2006.

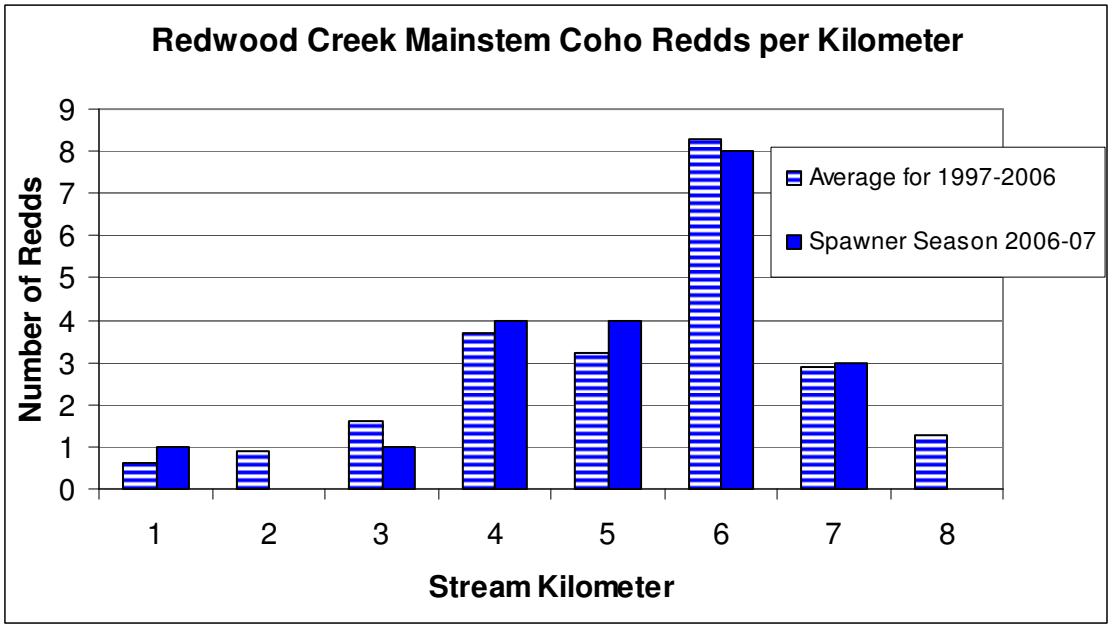


Figure 20. Redwood Creek mainstem, coho redds per kilometer for 2006-2007 compared with the average from 1997-2006.

A total of 3 definite coho redds were observed in Fern Creek during the 2006-2007 spawner season. Coho redds were discovered on December 16. The density of redds in the 1.0 km surveyed reaches of Fern Creek was 3 redds/km.

3.4.6 Redds (Steelhead)

A total of 11 definite steelhead redds were observed in the mainstem of Redwood Creek between January 9 and February 15. Steelhead redd observations were primarily concentrated in reach 2 representing 73% of confirmed steelhead redds. The total density of redds in the 7.4km mainstem section surveyed was 1.5 redds/km. In addition to the mainstem redds, there were also 4 steelhead redds identified in Fern Creek on February 15. The number of steelhead redds observed during the 2006-2007 spawning season was much higher then the average for the last 8 years of surveys (Figure 21).

3.4.7 Redwood Creek Escapement Estimates (Area Under the Curve)

Area Under the Curve (AUC) estimates were generated for live fish on Redwood Creek mainstem during 2006-2007. When possible residence time (RT) was estimated based on observations of female coho holding on redds with the RT period equaling the previous storm event at time of entrance to the last observation of an individual female coho holding on a redd location. Observations of individual female coho salmon at the same redd location from one survey week to the next were considered to be the same fish. AUC estimates were calculated based on RT and OE values from published coho spawner studies. Eight studies were reviewed

and had RT values ranging from eight to seventeen days. The most frequently reported values were eleven and thirteen days. Two of the eight studies reported OE values between 69 and 76 percent (Solazzi et al.1984, Johnston et al. 1987). To consider a wider range of observer efficiencies, AUC estimates were calculated for OE values between 50 and 100 percent.

Population estimates in the Redwood Creek mainstem ranged from 24 to 50 coho at 100% OE and 46 to 98 fish at 50% OE (Table 18). Based on our estimated OE and RT values, AUC estimates for coho salmon in Redwood Creek ranged from 39 to 51 returning spawners (Table 18).

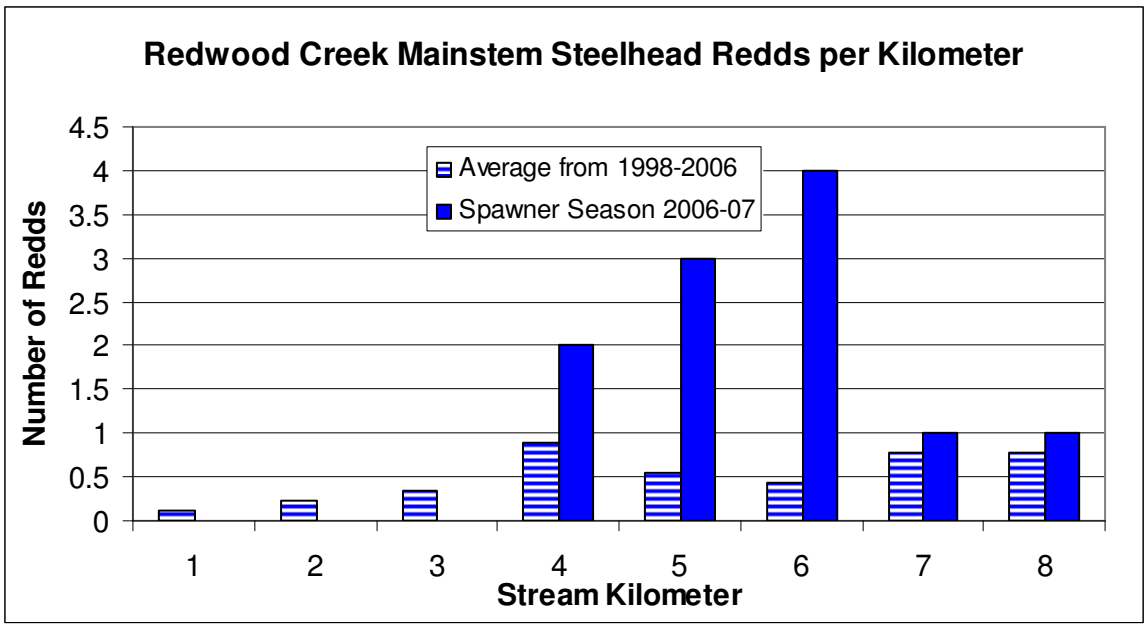


Figure 21. Redwood Creek mainstem, steelhead redds per kilometer for 2006-2007 compared with the average from 1998-2006.

3.4.8 Redwood Creek Escapement Estimates (Peak Live plus Cumulative Dead)

Due to the fact that coho return to spawn over a three-month period and residence time on the spawning grounds is variable, the same live fish are often double counted during repeated surveys. An index derived from adding the peak number of live fish observed during a single survey to the number of carcasses recovered prior to that date provides a minimum spawner estimate. The 2006-2007 peak live plus cumulative dead (PLD) index was 28 on the Redwood Creek mainstem and includes coho counts from November 20, December 16, and January 9.

Redwood Creek Watershed Escapement History: Escapement estimates for adults in Redwood Creek have been made using both the Peak Live plus cumulative Dead (PLD) and Area Under the Curve (AUC) method. In years where persistent high flows resulted in a low number of surveys, both methods likely under-represent the true escapement number.

3.4.9 PLD Index Results

The PLD dataset for adult escapement within Redwood Creek includes 16 years of survey information. It should be noted that prior to SY 1997-1998, redds and carcasses were not consistently counted. PLD estimates have ranged from 10 to 171 (Table 19). The results of SY 1999-2000, SY 2002-2003, and SY 2005-2006 are not considered representative of actual mainstem escapement due to poor survey conditions. The 2004-2005 spawner surveys had the highest PLD (171 adult coho) in the 16 year survey history. This is believed to be the strongest coho run since documentation of spawners were initiated in SY 1994-1995. This is further supported by the total number of observed redds and carcasses (93 and 76 respectively). The 2006-2007 spawner season was a disappointing one for Redwood Creek as returning spawners declined by over 50% for the year class.

Table 18. Area Under the Curve (AUC) population estimates for coho salmon adults during in Reaches 1-3 in the Redwood Creek mainstem during 2006-2007.

Residence Time	Observer Efficiency					
(days)	100%	90%	80%[f]	70%[c]	60%	50%
8[a]	50	56	63	70	82	98
9[b]	45	50	56	62	73	87
10[c]	40	45	50	56	65	79
11[d,e,f]	37	41	46	51	60	71
12	34	37	42	47	55	65
13[a,e,f,g]	31	34	39	43	50	60
14[g]	29	32	36	40	47	56
15[a]	27	30	34	37	44	52
16	25	28	31	35	41	49
17[a]	24	26	30	33	38	46

[a] Irvine et al. (1992)
[b] van der Berghe and Gross (1986)
[c] Flint (1984)
[d] Beidler and Nickelson (1980)
[e] Johnston et al. (1987): 69% observer efficiency
[f] Crone and Bond (1976)
[g] Koski (1966)
[h] Solazzi et al. (1984): 76% observer efficiency

Overall trends in coho spawning based on redds observed in the Redwood Creek watershed are shown in Figure 22. The three year classes are represented as primary colors (yellow-1, blue-2, and red-3) to show relationships between spawning runs. Year class 1 has remained relatively constant over the previous four generations but decreased during the spawner year 2006-2007. Year class 2 shows an increasing trend in spawning since spawner year 1995-1996. Year class 3 continues to struggle since a decline beginning with spawner year 1999-2000. Within each year the data is broken down into the creeks where spawning occurred. Year class 3 redds have been observed only in the mainstem of Redwood Creek, with a noticeable increase in the number of redds during the 2005-2006 spawner season. Year class 2 has a large component of spawning taking place in Kent Creek and Fern Creek. For all years the majority of spawning occurs in the mainstem of Redwood Creek.

Overall trends in coho spawning based on PLD escapement estimates in the Redwood Creek watershed are shown in Figure 23 with similar trends to those observed with number of redds. The three year classes are represented as primary colors (yellow-1, blue-2, and red-3) to show relationships between spawning runs. Year class 1 has remained relatively constant over the previous four generations but decreased during the spawner year 2006-2007. Year class 2 shows an increasing trend in spawning since spawner year 1995-1996. Year class 3 continues to struggle since a decline beginning with spawner year 1999-2000 with a slight increase in returning coho observed during the 2005-2006 spawner season.

Table 19. Coho salmon spawning survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for Redwood Creek Watershed.

Year	No. Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total Redds	Source
1969	1	6.7	24	4	--	CDFG
1977-1978	1	6.7	36	3	--	CDFG
1985-1986	1	6.7	50	--	--	CDFG
1994-1995	5	8.4 [a]	58	22	--	NPS Fong 1995
1995-1996	5	8.4 [a]	27	16	--	NPS Fong 1996
1996-1997	6	8.4 [a]	58	15	--	NPS Fong 1997
1997-1998	7	9.4 [b]	55	24	80	NPS Manning 1999
1998-1999	11	9.4 [b]	39 [c]	10	58	NPS CSRP
1999-2000	6	8.4 [a]	10	1	7*	NPS CSRP
2000-2001	5	9.4 [b]	49	11	34	NPS CSRP
2001-2002	5	9.4 [b]	106[d]	52	47	NPS CSRP
2002-2003	5	9.4 [b]	24[e]	3	5*	NPS
2003-2004	5	9.4 [b]	67	25	43	NPS
2004-2005	7	9.4 [b]	198[f]	76	93	NPS
2005-2006	5	9.4 [b]	30[e]	5	12	NPS
2006-2007	9	9.4 [b]	28[g]	6	24	NPS

[a]Includes the main stem of Redwood Creek and Fern Creek
[b]Includes the main stem of Redwood Creek, Fern Creek, and Kent Creek
[c]Includes two peaks, 7 weeks apart
[d]Includes two peaks, 22 days apart
[e]Includes two peaks, 33 days apart
[f]Includes two peaks, 25 days apart
[g]Includes three peaks, 26 and 24 days apart
*Poor survey conditions resulted in low observer efficiency

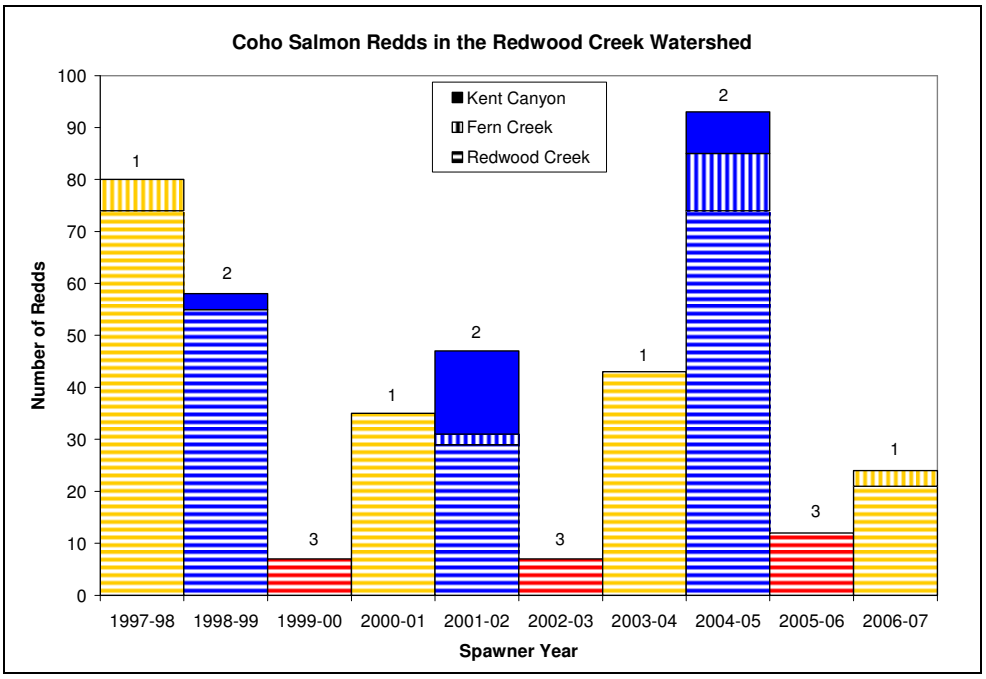


Figure 22. Coho salmon redd results by year class winter 1997-1998 through winter 2005-2006. Year classes are designated by color (Year Class 1 shown in yellow, Year Class 2 shown in blue, Year Class 3 shown in red) and creeks are designated by pattern (Redwood Creek in horizontal lines, Fern Creek in vertical, and Kent Creek in a solid color).

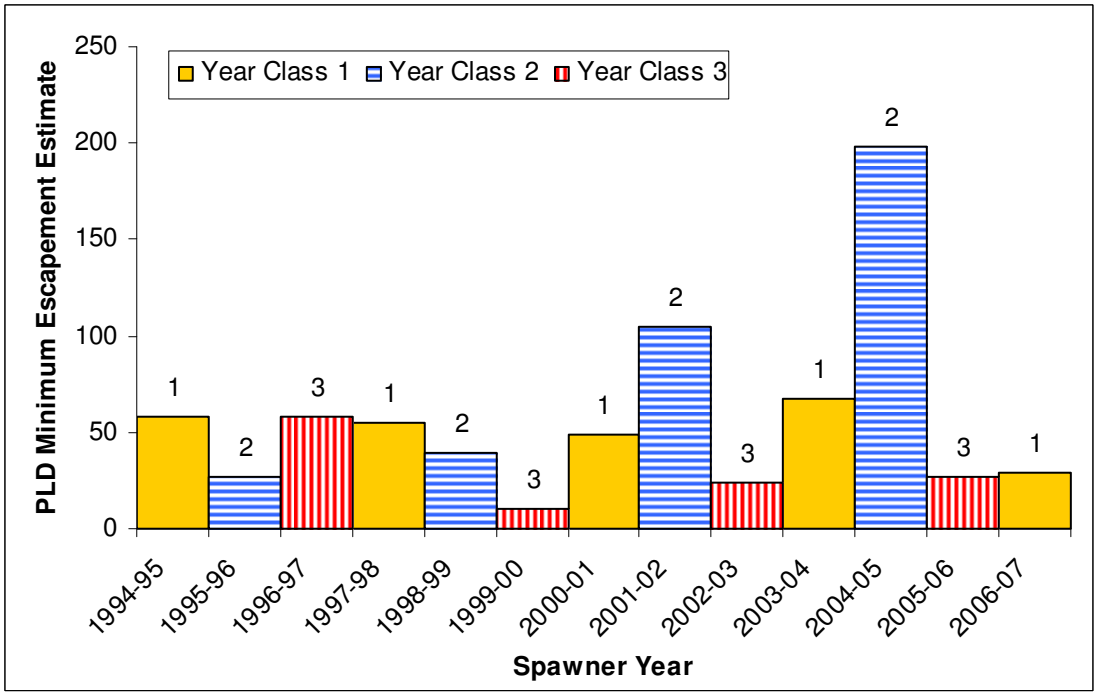


Figure 23. Redwood Creek Watershed, coho salmon Peak Live plus Cumulative Dead (PLD) Index escapement results winter 1994-1995 through winter 2006-2007.

Table 20. Coho salmon spawning survey Area Under the Curve (AUC) and Peak Live plus Cumulative Dead (PLD) estimates for Redwood Creek, 1997-1998 through 2006-2007. AUC estimates are given for 50%, 70-80%, and 100% Observer Efficiency (OE) and a Residence Time (RT) of 8-17 days.

Year	No. Surveys	Date of Entry	Mean Survey Interval (days)	Survey Length (km)	Auc Range 100% Oe Rt 8-17 Days	Auc Range 50% Oe Rt 8-17 Days	Auc Range 70-80% Oe Rt 11-13 Days	Redwood Creek PLD
1997-1998	7	23 Nov 97	7.5	9.4	89-188	177-376	145-195	65
1998-1999	11	29 Nov 98	8.6	9.4	39-83	78-167	64-87	39
1999-2000	6	01 Jan 00	11.8	8.4	8-17	16-35	13-18	10
2000-2001	5	15 Dec 00	13.0	9.4	74-157	148-314	121-163	49
2001-2002	5	07 Dec 01	11.3	9.4	116-247	233-494	190-257	105
2002-2003	5	10 Dec 02	14.0	9.4	22-46	43-92	35-48	24
2003-2004	6	11 Dec 03	6.3	9.4	43-91	86-182	70-94	67
2004-2005	7	06 Dec 04	8.3	9.4	169-359	338-718	276-373	171
2005-2006	5	01Dec 05	9.6	9.4	28-59	55-117	45-61	27
2006-2007	9	13 Nov 06	10.4	9.4	24-50	46-98	39-51	29

3.4.10 AUC Escapement Estimate

The PLD index is assumed to be a minimum count of fish within a watershed, as it is based on actual observations. The NPS has also used the AUC method to estimate adult escapement within Redwood Creek (Table 20). This method requires more consistent surveys and allows for an estimate of survey quality (observer efficiency) and the residence time of fish within the watershed. This method will tend to overestimate fish numbers where there are multiple peaks of fish or if there is a large interval between surveys. Only live fish are calculated using this technique. AUC estimates show a steady decrease in year class 1 during the 2006-2007 season, as well as a steady increase in year class 2 and 3.

3.4.11 Live Fish and Carcass biotics

Information on live fish and carcasses are collected during each field survey. Sex ratios for live fish and carcasses are reported for each spawner year in Table 21. While live fish lengths are estimated (length to nearest 5cm), carcasses are handled to definitively determine sex, spawn success, fork length (FL), and to collect a genetics sample. The results of carcass measurements show that males are generally between 65-75 cm, with females averaging 57-67 cm and jacks (two year old males) averaging from 37-47 cm. During the 2006-2007 season, no adult male coho carcasses were recovered, the average fork length of female carcasses recovered was 66cm, and only one jack measuring 44 cm was recovered (Table 21).

3.4.12 Redwood Creek Watershed Summary

The emerging picture from 13 winters of coho spawner surveys on Redwood Creek (see Figure 20, Table 21) reveals the presence of one currently strong but variable year class (year class 2), one weak year class (year class 3), and one moderate year class that may be in decline (year class 1). Previously, year class 3 was probably as strong as year class 1, with a PLD index of 57 during the 1996-1997 spawning run. However, the resulting cohort probably suffered high mortality during the last large-scale El Nino Southern Oscillation (ENSO) event in 1997-1998. This event caused high flows during the winter of 1997-1998 which may have resulted in low over winter survival for the juvenile coho. Results of adult escapement and summer juvenile density monitoring indicate that the over wintering year class during the height of El Nino was the most heavily impacted and marks the shift of that cohort to the weakest year class. Although low spawner counts for the last three runs of this year class may be due in part to poor survey conditions, juvenile density observations support the notion that this became, and now remains the weakest year class.

Table 21. Sex ratios and size measured by fork length (FL) of live coho and carcasses within Redwood Creek. Standard deviation is refered to as SD.

Year	Month	Live Coho				Carcasses			
		#	%	Mean FL	FL SD	#	%	Mean FL	FL SD
1997-	M	12	26%	57.9(n=12)	5.42	6	25%	56.0(n=3)	6.6
1998	F	24	52%	56.9(n=24)	4.85	7	29%	54.8(n=6)	4.1
	J	4	9%	40.0(n=4)	0.00	4	17%	39.7(n=7)	1.3
	Unk	6	13%	53.3(n=6)	4.08	7	29%	60.0(n=2)	7.1
	All	46	100%			24	100%		
1998-	M	8	22%	61.3(n=8)	3.54	2	14%	62.0(n=2)	2.8
1999	F	16	44%	53.8(n=16)	3.87	6	43%	52.3(n=6)	2.6
	J	6	17%	36.7(n=6)	5.16	5	36%	42.2(n=5)	2.6
	Unk	6	17%	55.0(n=6)	4.5	1	7%		
	All	36	100%			14	100%		
1999-	M	3	33%	56.7(n=3)	11.6	0	0		
2000	F	4	44%	62.5(n=5)	11.9	1	100%	55.0(n=1)	
	J	0	0			0	0		
	Unk	2	22%	67.5(n=2)	3.5	0	0		
	All	9	100%			1	100%		
2000-	M	4	9%	60.0(n=4)	7.1	3	23%	62.5(n=2)	3.5
2001	F	14	30%	55.0(n=14)	4.4	6	46%	66.8(n=5)	2.9
	J	28	61%	39.1(n=28)	4.3	3	23%	42.7(n=3)	4.6
	Unk	0	0			1	8%	55.0(n=1)	
	All	46	100%			13	100%		
2001-	M	52	56%	59.2(n=51)	8.3	19	37%	70.1(n=19)	6.3
2002	F	31	33%	56.7(n=30)	6.3	20	38%	65.4(n=20)	5.3
	J	1	1%	45.0(n=1)		0	0		
	Unk	9	10%	57.1(n=7)	7.0	13	25%	64.9(n=7)	4.6
	All	93	100%			52	100%		
2002-	M	2	13%	65.0(n=2)	7.1	0	0		
2003	F	10	67%	53.6(n=7)	3.8	1	20%	50.0(n=1)	
	J	2	13%	42.5(n=2)	3.5	4	80%	36.5(n=4)	8.2
	Unk	1	7%	55.0(n=1)		0	0		
	All	15	100%			5	100%		
2003-	M	19	32%	62.0(n=19)	7.0	10	36%	63.8(n=8)	7.3
2004	F	26	43%	59.6(n=25)	4.6	13	46%	64.2(n=12)	5.4
	J	13	22%	35.4(n=13)	6.9	2	7%	40.5(n=2)	0.7
	Unk	1	2%	55.0(n=1)		3	11%	64.0(n=2)	1.4
	All	59	99%			28	100%		
2004-	M	69	40%	65.1(n=68)	5.5	18	26%	67.2(n=15)	4.7
2005	F	82	48%	60.1(n=78)	5.1	40	58%	63.3(n=40)	4.8
	J	9	5%	38.3(n=9)	2.5	1	1%	70.0(n=1)	
	Unk	11	6%	60.6(n=8)	6.2	10	14%	49.0(n=1)	
	All	171	100%			69	100%		
2005-	M	8	21%	69.4 (n= 8)	14.7	2	40%	57.0 (n=2)	1.4
2006	F	13	34%	60.4 (n=12)	5.8	3	60%	62.0 (n=3)	1.7
	J	12	32%	38.7 (n=12)	4.8	0			
	Unk	5	13%	57.0 (n=5)	2.7	0			
	All	38	100%			5	100%		
2006-	M	13	30%	63.4 (n=13)	4.7	0			
2007	F	26	59%	60.4 (n=26)	3.7	4	66%	66.0 (n=4)	5.8
	J	1	2%	45.0 (n=1)		1	17%	44.0 (n=1)	
	Unk	4	9%	57.5 (n=4)	2.9	1	17%	62.0 (n=1)	
	All	44	100%			6	100%		

3.5 Pine Gulch Creek Coho Escapement

Spawner surveys were initiated on Pine Gulch in 2000. For more detailed results on individual surveys performed during the 2006-2007 spawner season please see the 2006-2007 Annual Escapement Report (Del Real 2007). Pine Gulch Creek spawner survey information includes data collected from 9.5km within two reaches (see Figure 6). Four spawner surveys were conducted on Pine Gulch between November 30 and January 25 (Table 22).

3.5.1 Survey Timing and Environmental Conditions

Between November 30, 2006 and January 25, 2007, four spawner surveys were conducted on Pine Gulch Creek (see Table 8). The mean interval between surveys was fourteen days. Average water clarity at the time of surveys ranged from 70cm to 100cm.

Table 22. Seven day total rainfall per Julian week, average water clarity, and the number of coho redds, coho carcasses, and live coho observed in 2006-2007 on the mainstem of Pine Gulch Creek.

Julian Week	Survey Date	Survey Reaches	Calendar Day	7 Day Rainfall During Julian Week* (in)	Average Survey Water Clarity (cm)	Coho Redds	Coho Carcass	Live Coho
46	13 Nov 06			3.77				
47				0.2				
48	30 Nov 06	1	334	1.42	70	0	0	0
49				1.09				
50				5.9				
51	19 Dec 06	1-2	353	1.57	85	0	0	0
52				1.43				
53				0				
1	05 Jan 07	1-2	5	1.28	70	0	0	0
2				0				
3				0.02				
4	25 Jan 07	1-2	25	0.5	100	0	0	0
5								

*Rainfall totals contain possible discrepancies between actual and reported due to loss of power to gage and/or possible debris within gage.
Reach 1: Olema-Bolinas Road Bridge to Copper Mine Gulch Confluence (6.0 km)
Reach 2: Copper Mine Gulch Confluence to upstream of Teixeira to approximately monument marker 100 (3.5 km).

3.5.2 Live Fish, Carcass, and Redd Observations

No live adult coho spawners, coho carcasses, or coho redds were observed during the 2006-2007 spawner surveys on Pine Gulch Creek. No steelhead were discovered during the four spawner surveys but adult steelhead were observed on Pine Gulch into mid-April.

3.5.3 Pine Gulch Creek Watershed Escapement History

The dataset for the adult escapement within Pine Gulch Creek includes seven years of survey information following the discovery of one adult coho salmon during the SY 2000-2001. Since this discovery, live adult coho and/or coho spawning activity have been sighted in the watershed during five out of the seven years (Table 23). Summer juvenile coho surveys and spring downstream migrant traps have confirmed that a self propagating coho run does occur in Pine Gulch Creek.

Table 23. Coho salmon spawning survey including Peak Live plus Cumulative Dead (PLD) Index, tally of total carcasses, and total redds for the Pine Gulch Creek mainstem.

Year	Year Class	No. Surveys	Survey Area (km)	PLD Index	Total Carcasses	Total New Redds	Source
2000-2001	1	3	7.0	1	0	0	NPS-PRNS
2001-2002	2	2	9.0	2	0	2	NPS-PRNS
2002-2003	3	2	8.0	2	2	1	NPS-PRNS
2003-2004	1	6	9.0	0	0	0	NPS-PRNS
2004-2005	2	3	10.0	3	0	3	NPS-PRNS
2005-2006	3	4	9.5	1	0	1	NPS-PRNS
2006-2007	1	4	9.5	0	0	0	NPS-PRNS

3.5.4 Pine Gulch Creek Watershed Summary

Year class 2 appears to be strongest year class on Pine Gulch followed by year class 3 and 1. Although no returning adults or definite redds were observed during the 2003-2004 spawner year, a basin wide survey conducted on Pine Gulch during the summer of 2004 revealed the presence of juvenile coho in the watershed (Ketcham et al. 2005). During the 2006-2007 spawner season no live coho, coho carcasses, or coho redds were observed. Snorkel surveys conducted during the summer of 2007 confirmed the absence of coho from this year class.

3.6 Spring Outmigration Rainfall

Rainfall amounts were collected from a rain gage located at the Bear Valley Headquarters and was used to represent the rainfall for all three trapping operations (Figure 26). Of note are the 1.57 inches received over the course of 48 hours on April 21 and 22. In general, conditions remained dry throughout the trapping season resulting in below average spring rainfall. This was especially true for the month of March in which the Bear Valley Headquarters only received 0.05 inches of rain for the entire month which was well below the average of 5.48 inches.

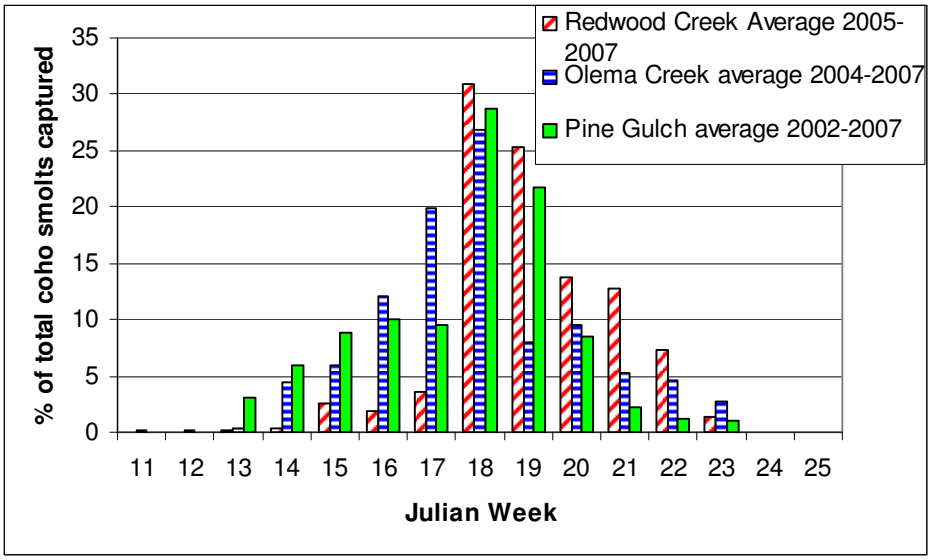


Figure 24. Percent of total coho smolts captured during 2007 compared to the running average by Julian week in Redwood Creek (2005-2007 running average), Olema Creek (2004-2007 running average), and Pine Gulch Creek (2002-2007 running average).

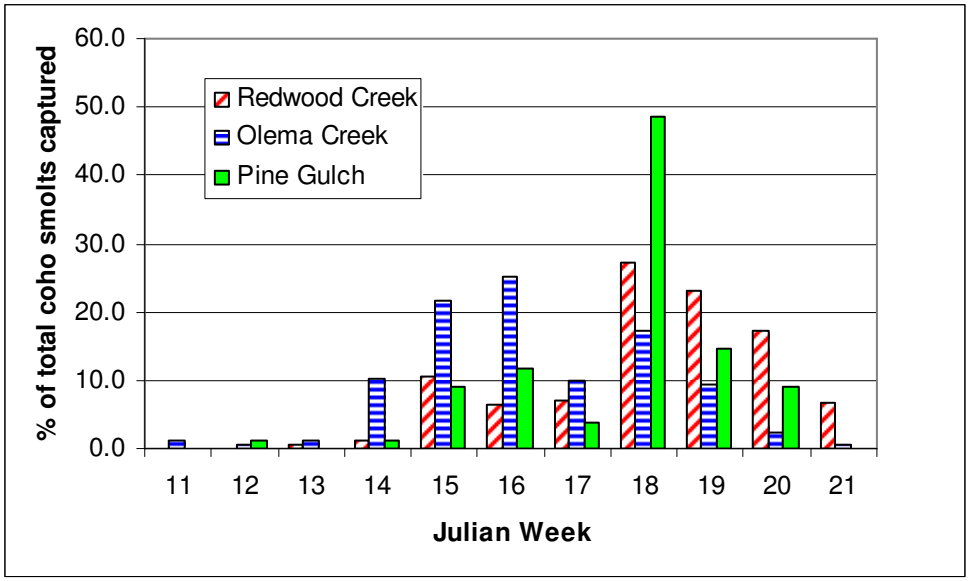


Figure 25. Percent of total coho smolts captured by Julian week for Redwood, Olema, and Pine Gulch Creeks, during 2007.

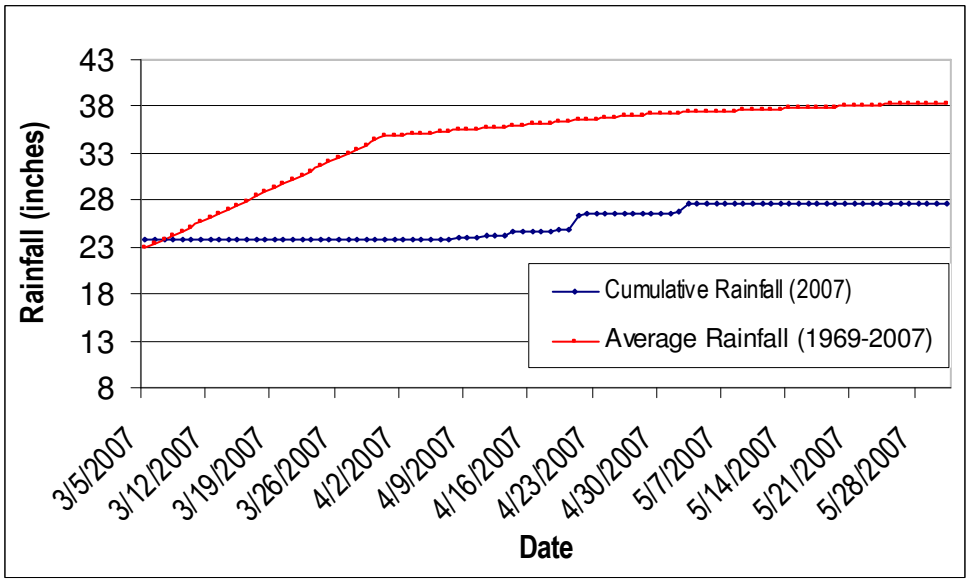


Figure 26. Cumulative rainfall amounts for Bear Valley Headquarters Complex, March 5-May 31, 2007 compared to average rainfall during the same period 1969-2007.

3.7 Spring Smolt Trap Water Temperature

Water temperatures within trap boxes were within the tolerable temperature range (< 22ºC) for coho salmon (Moyle 2002) during the entire trapping season at all three trapping locations. The highest average and maximum temperature recorded was in Olema Creek with an average temperature of 13.4 ºC (2.1 SD) and a maximum temperature of 19.86 ºC. The lowest minimum temperature was recorded on Redwood Creek with a minimum temperature of 6.75 ºC. The

lowest average temperature was recorded on Pine Gulch Creek with an average temperature of 11.9 ºC (1.4 SD). Average temperatures for both Olema and Redwood Creek fell within the optimal temperature range for juvenile coho rearing (12ºC to 14ºC) (Moyle 2002) with the average temperature for Pine Gulch (11.9 ºC) falling just below this range.

3.8 Olema Creek Smolt Outmigration Results

Results for smolt trapping are reported by Julian week (Appendix C) to support analysis between monitoring years and watersheds. In all years trapping operations were conducted within an eleven week time frame starting in mid March and ending in early June. Actual start and end dates for each year vary depending on instream flows, stream temperature, and coho smolt captures. Trapping operations were initiated on Olema Creek in 2004. For a detailed account of trapping operations during the 2007 trapping season please see the 2007 Annual Smolt Trapping Summary (Del Real 2007).During the 2007 outmigrant trapping study, the Olema Creek trap was in place for 74 days (from March 14 through May 27) and was fully operational for 73 days.

The trap captured a total of 330 coho smolts. The trap also captured a total of 224 1+ steelhead smolts, nine 1+ steelhead presmolts and 134 steelhead 1+ parr (Table 24). This was the highest number of steelhead smolts and parr captured since trapping was initiated in 2004. Mark/recapture data stratified by week resulted in an estimated capture probability at approximately 30% throughout the duration of the trapping operation resulting in a total coho smolt estimate of 1,098 (±116 s.d.), which is below the running average of 3,442 smolts.

Peak capture for coho smolts/presmolts occurred in mid April, during week 16 which is two weeks earlier than the running average (Figure 27). The earlier migration pattern may be due to the new trapping location which is approximately one kilometer upstream of the trapping location used in years 2004-2006.

Also captured during this season were 1,201 fry, of which 739 (62%) were coho and 462 (38%) were steelhead. Coho fry capture peaked at the end of April (Week 17), and steelhead fry capture peaked in mid May (Weeks 20 and 21). While steelhead fry captures were average when compared to previous years (579 fry), coho fry captures were the highest since trapping operations were initiated in 2004.

A total of twelve adult steelhead were incidentally captured in the smolt trap during their migration back to the ocean from late March to mid May. This was the highest number of adult steelhead captured since trapping operations were initiated during the spring of 2004.

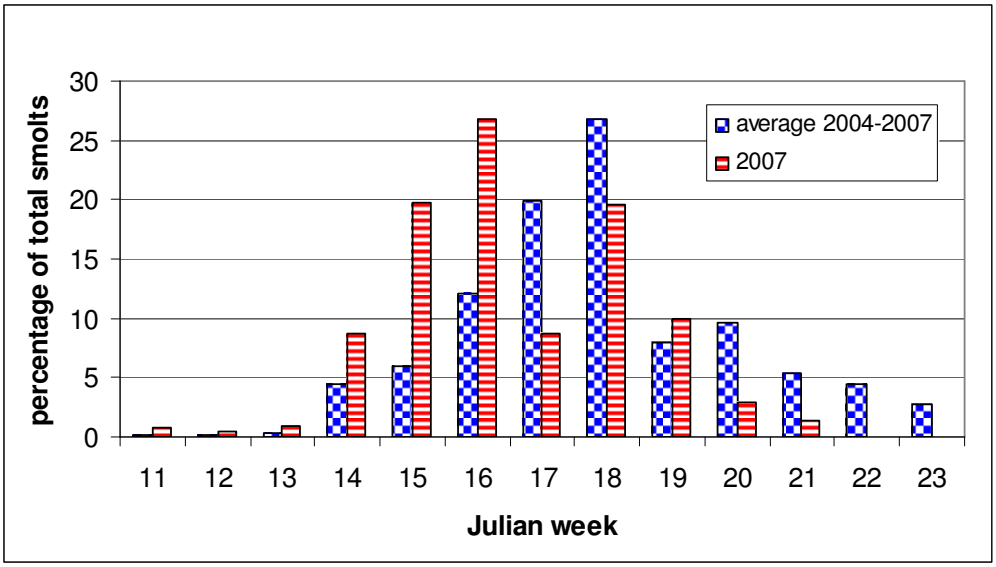


Figure 27. Percent of total coho smolts captured by Julian week for Olema Creek in 2007 compared to the running average 2004-2007.

3.8.1 Olema Creek Smolt Outmigration History

During the 2007 smolt trapping operations, Olema Creek had a calculated production estimate of 1,098 (± 116) coho smolts (Table 24). The running average of 3,442 coho smolts, calculated for the four years of monitoring, is most likely inflated by the high variability in the 2006 smolt production estimate. Excluding the 2006 smolt production estimate from the running average is 1,075 smolts, which is comparable to the 2007 smolt production estimate.

The highest coho production estimate for Olema Creek occurred during the spring of 2006 with an estimated production of 10,544 (± 8,399) coho smolts. The high variability for the spring of 2006 resulted from limited recapture of marked individuals (<10% of marked individuals). In addition to installing the trap two weeks later than normal due to high flows, there were two significant spring rainfall events that prevented trap operation during 9 of the 54 trapping days.

The 2007 coho smolt production estimate for Olema Creek is approximately 20% higher than the spring 2004 outmigration estimate (Table 24). In addition, this outmigration estimate suggests an overwinter survival rate of approximately 61.2%, when compared with the summer 2006 juvenile population estimate (see Table 74, page 136).

Smolt size (both length and weight) is directly related to ocean survival (Miller and Sandros 2003) with smolts being of larger size at time of ocean entrance having a higher chance at surviving to adult. In Olema Creek, the mean smolt length and weight between 2004 and 2007 is 109.89 millimeters and 13.40 grams (Table 27). It should be noted that in all years, except 2006, mean coho smolt length and weight are comparable. The 2006 coho smolts stand out as anomalous (Figures 28 & 29) with outmigrants that spring approximately 10% shorter and 25% lighter than observed in other years on Olema Creek. Based on our continued monitoring this substantial size difference may have resulted in severe ramifications related to the adult return of this year class.

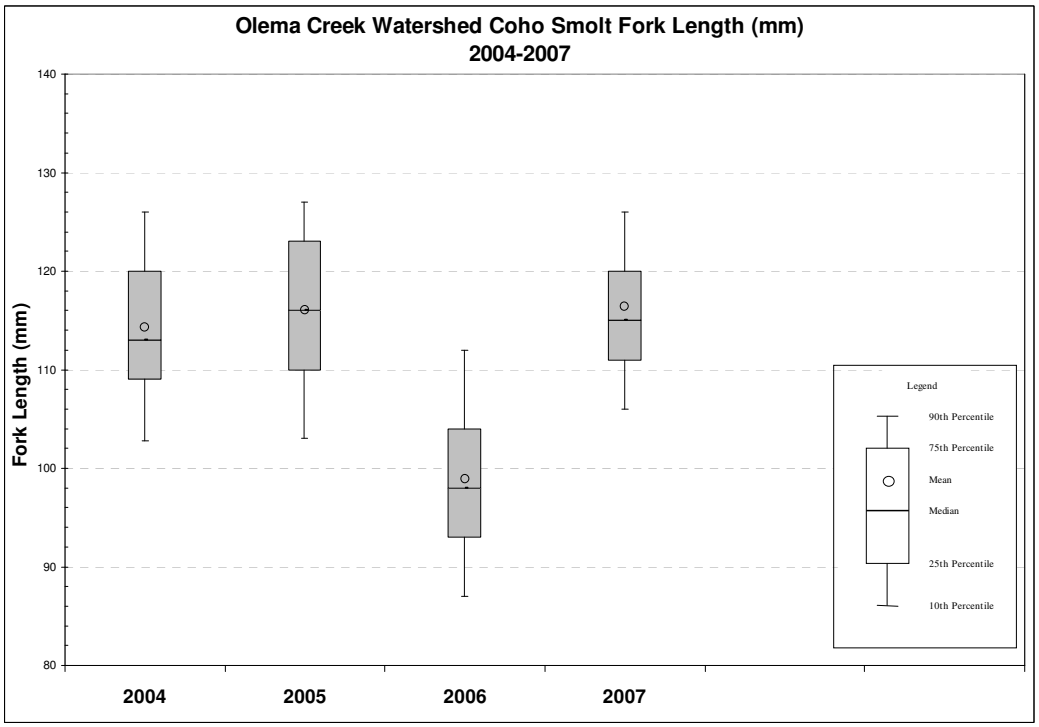


Figure 28. Fork length of coho salmon smolts in Olema Creek, 2004-2007.

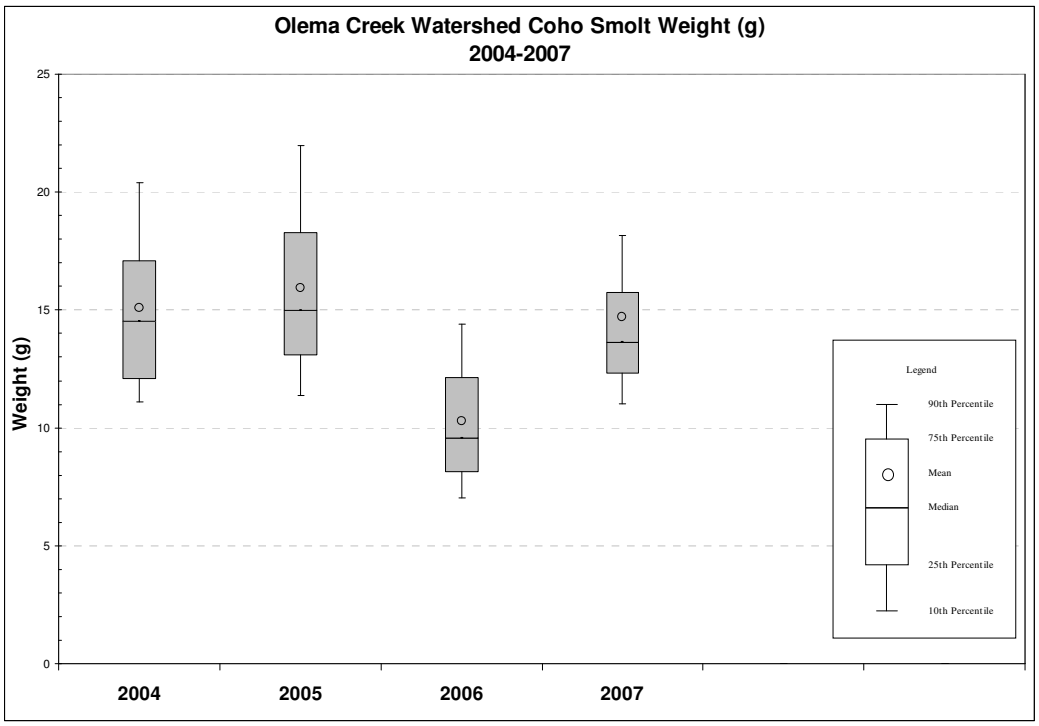


Figure 29. Weight of coho salmon smolts in Olema Creek, 2004-2007.

The 2007 steelhead results for both smolts and ocean run adults dramatically exceeded observations in previous years. Prior to the 2007 observation of 233 steelhead smolts, the previous high was 13 (in 2004). In addition, there were 12 ocean-run steelhead observed in 2007, where only one ocean-run adult was observed in the previous three years of trapping.

Table 24. Summary of salmonid information for Olema Creeks trap operations, 2004-2007. Coho and steelhead presmolts are included in the coho and steelhead smolt totals.

	Trap Operation Dates		Steelhead					Coho		Coho Production Estimate	
			Juvenile			Adult					
Year	From	To	Smolt	Parr	Fry	Resident	Ocean-run	Smolt	Fry	Estimate	SD
2004	30-Mar	28-May	13	5	140	0	0	229	32	831	± 167
2005*	1-Apr	9-May	9	8	1,218	0	1	87	14	1,296	± 724
2006**	10-Apr	9-Jun	6	19	497	0	0	368	51	10,544	± 8,399
2007	14-Mar	27-May	233	134	462	2	12	330	739	1,098	± 116

*Trapping discontinued May 9 due to high flows and presence of California red-legged frog tadpoles. Trap was not reinstalled.
**Trap was functional 45 of 54 operational days due to high flows.

3.9 Redwood Creek Smolt Outmigration Results

Results for smolt trapping are reported by Julian week (Appendix C) to support analysis between monitoring years and watersheds. In all years trapping operations were conducted within an eleven week time frame starting in mid March and ending in early June. Actual start and end dates for each year vary depending on instream flows, stream temperature, and coho smolt captures. Trapping operations were initiated on Redwood Creek in 2005. For a detailed account of trapping operations during the 2007 trapping season please see the 2007 Annual Smolt Trapping Summary (Del Real 2007).

During the 2007 outmigrant trapping study, the Redwood Creek trap was in place for 72 days (from March 16 through May 27) and was fully operational for 71 days. The trap captured a total of 330 coho smolts and 17 steelhead smolts (Table 25). Mark/recapture data stratified by week resulted in an estimated capture probability at approximately 68% during the first three weeks of the marking schemes, then decreasing to approximately 47% during the final weeks of sampling, resulting in a total coho smolt estimate of 520 (±126). Peak capture for coho smolts occurred in mid April, during week 18 similar to the running average migration pattern for the past three years of trapping (Figure 30).

Also captured during this season were 682 fry, of which 97 (14%) were coho and 585 (86%) were steelhead. This was the highest number of steelhead fry captured since trapping was initiated in 2005. One adult steelhead was incidentally captured in the smolt trap on March 31 and immediately released so it could continue its migration back to the ocean.

3.9.1 Redwood Creek Smolt Outmigration History

The highest coho production estimate measured during the three years of trapping on Redwood Creek occurred during 2006 with an estimated coho smolt production of 3,253 (± 542). In general, the low confidence intervals for coho smolt estimates in Redwood Creek are indicative of high recapture rates of marked individuals, and an efficient trapping site.

The 2007 coho production estimate of 520 (± 123) for Redwood Creek is far below the running average of 2,085 smolts. This result represents the lowest coho smolt production estimate for Redwood Creek (Table 25), but represents an estimated 49.5% overwinter survival with respect to the summer 2006 juvenile population estimate (see Table 76, page 138).

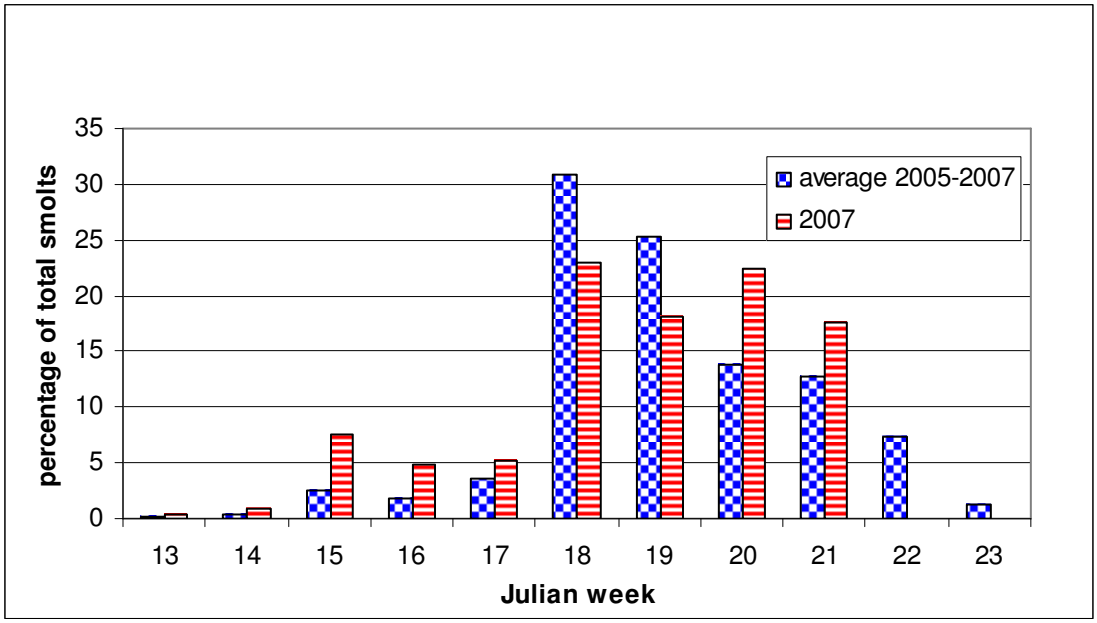


Figure 30. Percent of total coho smolts captured by Julian week for Redwood Creek in 2007 compared to the running average 2005-2007.

Smolt size (both length and weight) is directly related to ocean survival (Miller and Sandros 2003) with smolts being of larger size at time of ocean entrance having a higher chance at surviving to adult. In Redwood Creek, the mean smolt length and weight between 2005 and 2007 is 103.33 millimeters and 10.89 grams (Table 29). Length and weight of outmigrating smolts were similar in 2005 and 2006, with much larger and heavier smolts observed in 2007 (Figures 31 & 32). Based on our continued monitoring this substantial size difference may have resulted in severe ramifications related to the adult return of the year classes associated with outmigration in spring 2005 and spring 2006.

Limited numbers of steelhead smolts or adults have been observed in the Redwood Creek trap in all years.

Table 25. Summary of salmonid results for Redwood Creek trap operations, 2005-2007. Coho and steelhead presmolts are included in the coho and steelhead smolt totals.

Year	Trap Operation Dates		Steelhead					Coho		Coho Production Estimate	
			Juvenile			Adult					
	From	To	Smolt	Parr	Fry	Resident	Ocean-run	Smolt	Fry	Estimate	SD
2005	27-Mar	31-May	1	1	344	0	0	301	535	2,481	± 616
2006	18-Apr	9-Jun	18	0	24	0	0	1048	27	3,253	± 542
2007	16-Mar	27-May	17	5	585	0	1	330	97	520	± 126

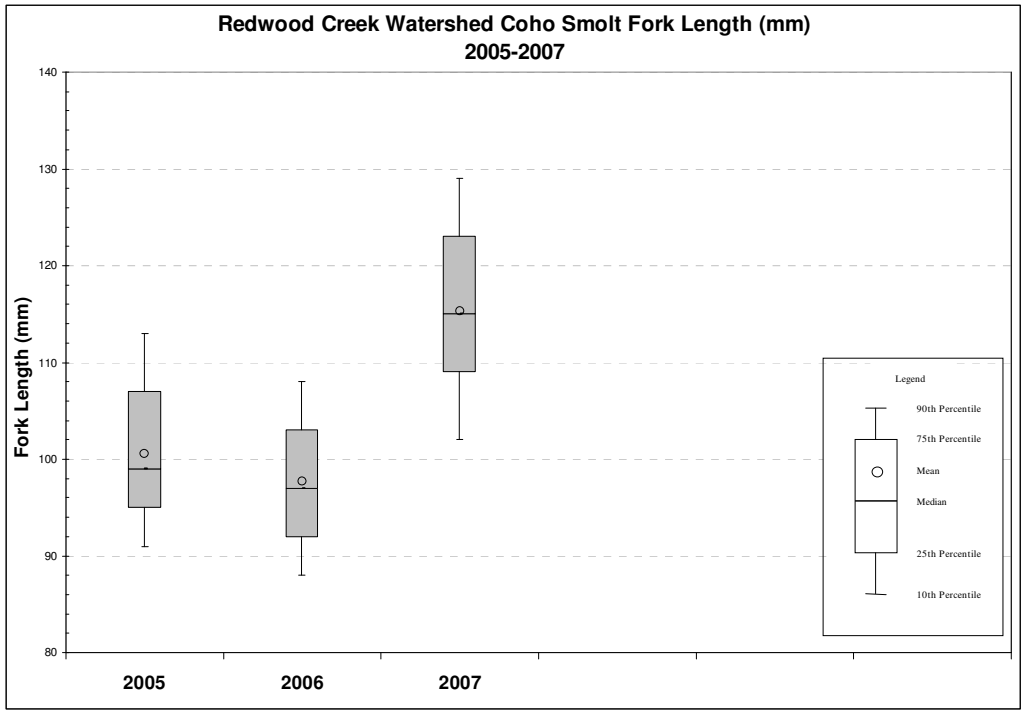


Figure 31. Fork length of coho salmon smolts in Redwood Creek, 2005-2007.

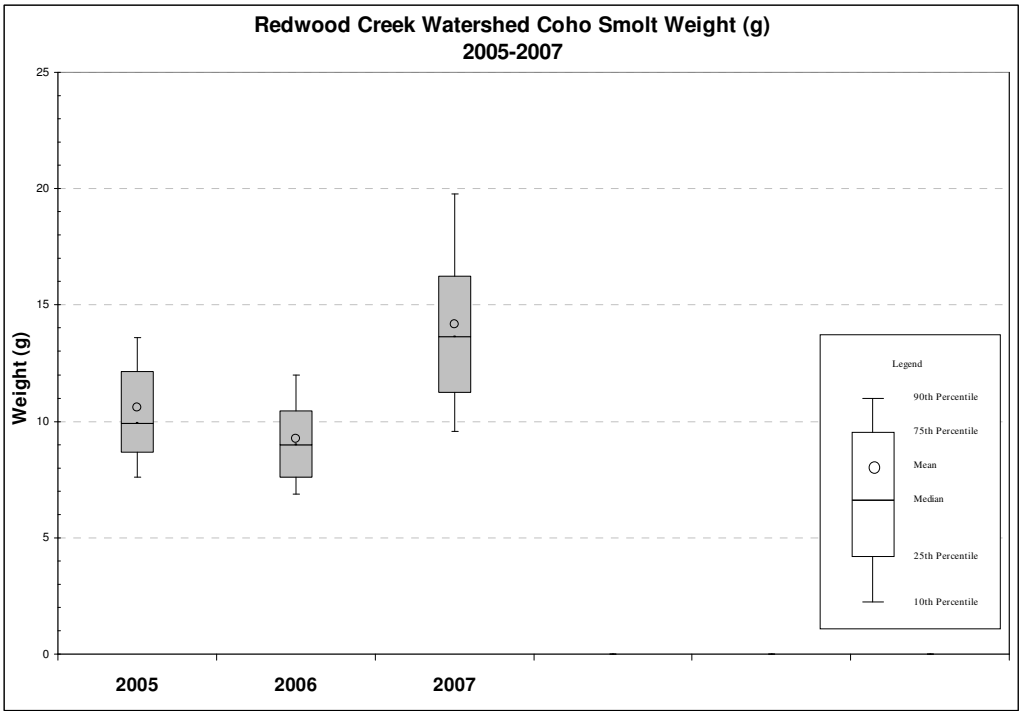


Figure 32. Weight of coho salmon smolts in Redwood Creek, 2005-2007.

3.10 Pine Gulch Creek Smolt Outmigration Results

Results for smolt trapping are reported by Julian week (Appendix C) to support analysis between monitoring years and watersheds. In all years trapping operations were conducted within an eleven week time frame starting in mid March and ending in early June. Actual start and end dates for each year vary depending on instream flows, stream temperature, and coho smolt captures. Trapping operations were initiated on Pine Gulch in 2002. For a detailed account of trapping operations during the 2007 trapping season please see the 2007 Annual Smolt Trapping Summary (Del Real 2007). During the 2007 outmigrant trapping study, the Pine Gulch trap was in place for 74 days (from March 14 through May 27) and was fully operational for 73 days.

The trap captured a total of 76 coho smolts, 82 steelhead 1+, including 44 smolts, one presmolt and 37 parr (Table 26). The total coho smolt capture was low when compared to the running average for the past six years (192 smolts). Mark/recapture data stratified by week resulted in an estimated capture probability at nearly 35% for the duration of the trapping operation. The estimated capture efficiency resulted in a total coho smolt estimate of 219 (±33 s.d.). Peak capture of coho smolts/presmolts occurred in early May during Week 18 (Figure 33). Peak coho fry captures for 2007 were similar to past years when compared to the running average from the past six years of data.

Also captured during this season were 3,147 steelhead fry which was the highest number of fry captured since trapping was initiated in 1999. The high number of steelhead fry captured may have been the result of a steelhead redd located directly upstream of the trapping location or above average steelhead spawning in the watershed. Modifications to the trap, including a screen in the box with larger mesh to let fry through, have been employed at the trap to alleviate this

problem in the future. No coho fry were captured. Seven adult steelhead were incidentally captured in the smolt trap during their migration back to the ocean.

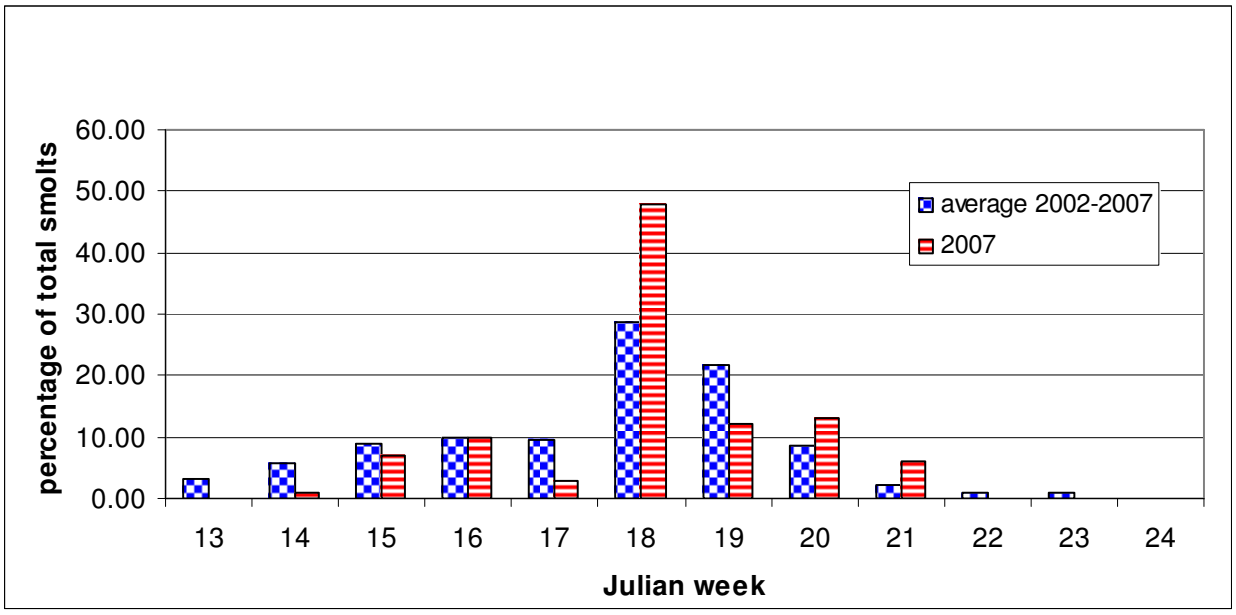


Figure 33. Percent of total coho smolts captured by Julian week for Pine Gulch in 2007 compared to the running average 2002-2007.

3.10.1 Pine Gulch Creek Smolt Outmigration History

The highest coho population during the seven years of smolt trapping operations on Pine Gulch occurred during 2004 with an estimated production of 737 (± 144) coho smolts (Table 26). It should be noted that in 2003, prior to use of mark-recapture techniques, a total of 550 coho smolts were captured. In 2007, a total of 75 coho smolts were captured with a production estimate of 219 (± 33).

Pine Gulch Creek represents the longest continuous smolt trapping dataset (2002-2007). Figures 34 and 35, and Table 31 shows that for all monitoring years, except 2006, the length and weight of coho smolts was generally consistent (ranging between 105 – 115 millimeters, and 12-15 grams). The 2006 smolt outmigrants present a smolt size anomaly observed in all monitored watersheds (Olema, Redwood and Pine Gulch Creek). In this case, the Pine Gulch coho smolts were approximately 10% shorter and 20% lighter than smolts observed in any other year. Because the 2006 smolts were smaller in all watersheds monitored, a regional environmental condition, such as rainfall, runoff, or temperature is a more likely scenario.

Table 26. Summary of salmonid information for Pine Gulch Creeks trap operations, 1999-2007. Coho and steelhead presmolts are included in the coho and steelhead smolt totals.

Year	Trap Operation Dates		Steelhead					Coho		Coho Production Estimate	
			Juvenile			Adult					
	From	To	Smolt	Parr	Fry	Resident	Ocean-run	Smolt	Fry	Estimate	SD
1999	16-Apr	24-May	62	42	65	1	0	0	0	N/A	N/A
2002	28-Mar	29-May	27	27	240	0	5	249	0	N/A	N/A
2003	28-Mar	30-May	282	120	235	1	1	576	1	N/A	N/A
2004	25-Mar	28-May	49	50	57	0	0	149	0	737	± 144
2005	31-Mar	31-May	28	10	200	0	0	8	0	N/A	N/A
2006	26-Apr	9-Jun	11	7	2	0	0	93	1	368	± 76
2007	14-Mar	27-May	45	37	3,147	0	7	76	0	219	± 33

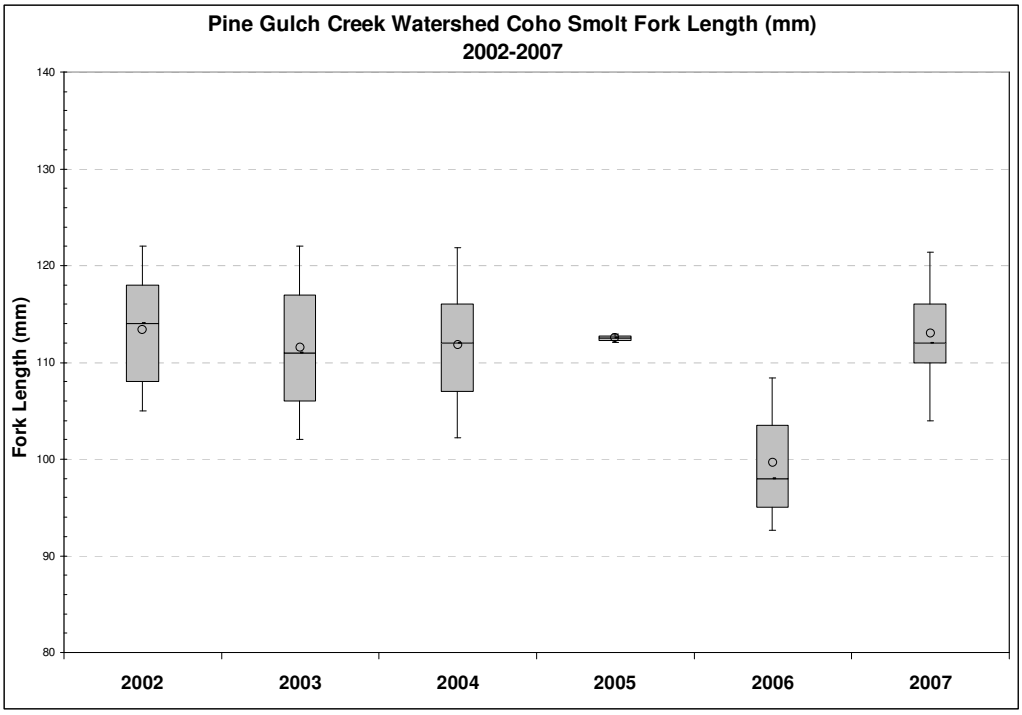


Figure 34. Fork length of coho salmon smolts in Pine Gulch Creek, 2002-2007.

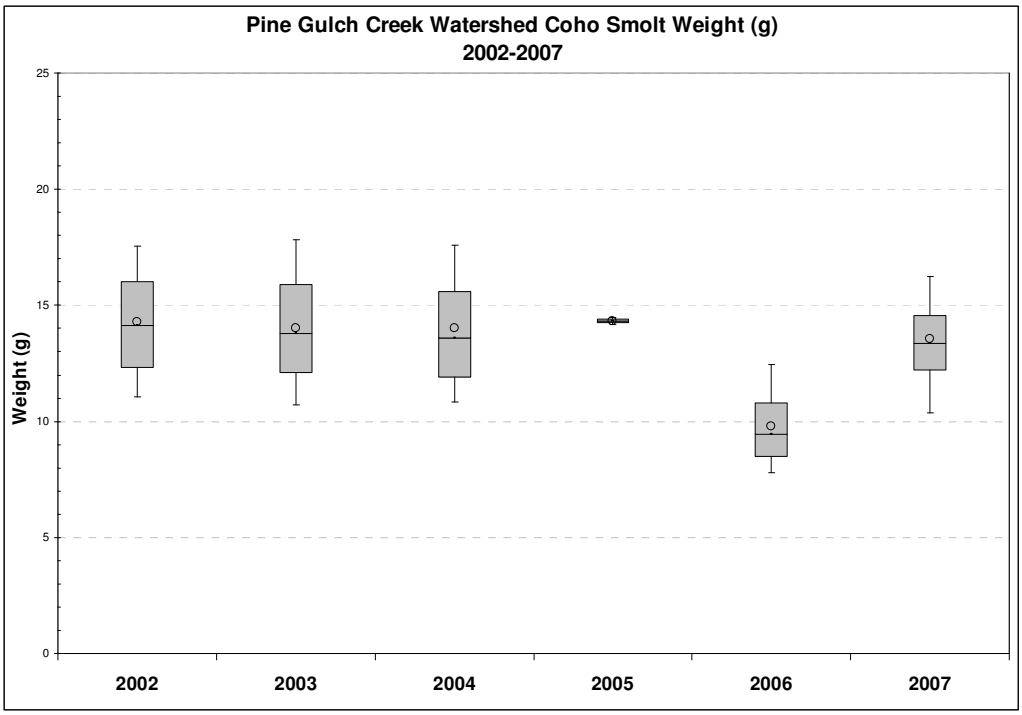


Figure 35. Weight of coho salmon smolts in Pine Gulch Creek, 2002-2007.

3.11 Smolt Size and Condition

A variety of research has shown that ocean survival of smolts is dependent on fish size as they enter the ocean (Miller and Sandros 2003). Within intermittent stream systems such as upper Olema Creek, Pine Gulch, and Redwood Creek, fish tend to grow in the spring and early summer when feeding conditions are best. In the summer, as surface flow recedes, isolated and intermittent pools form. Within these isolated pools, water temperatures increase and the food supply decreases dramatically. Temperature and dissolved oxygen stratification in these pools often occurs, with cool water and adequate DO near the bottom. Although pools become isolated between June and October, from our observations, they still support salmonid species (both coho and steelhead). Feeding rates are reduced during these low flow summer months. Salmonids must quickly catch up in the late fall, prior to major winter storms, and during the spring, before outmigrating to the ocean. It is clear that these fish have the capacity to "catch up" as shown in growth patterns of the fish. Access to floodplain habitat during the winter and early spring is also important to support growth of salmonids prior to smoltification.

Length and weight data provide critical information that contributes to the understanding of fish heath, survival, and condition factors. In addition, length and weight data allow for estimating fork length frequency, growth rates, and biomass production. Throughout the 2007 smolt trap operations, staff recorded fork lengths (FL) and weights of a subsample of fish caught in the trap. Analysis of fork-length frequency, weight-length relationships, and Fulton Condition Factor are included for coho salmon and steelhead for each of the three smolt trap locations.

3.11.1 Fork Length Frequency

Histograms of salmonid fork length frequencies are presented for Olema Creek coho (Figure 36) and steelhead (Figure 37); Redwood Creek coho (Figure 38) and steelhead (Figure 39); and Pine Gulch coho (Figure 40) and steelhead (Figure 41). Average frequencies are also provided as a comparison between the smolt production in 2007 and the running average from all years surveyed. Such comparisons can be used to determine if seasonal or anthropogenic events caused a detrimental effect to the health of the population. A comparison of average fork length frequencies for all three watersheds for coho (Figure 42) and for steelhead (Figure 43) are provided to determine if variations in realitive fish size occur between these key populations exist.

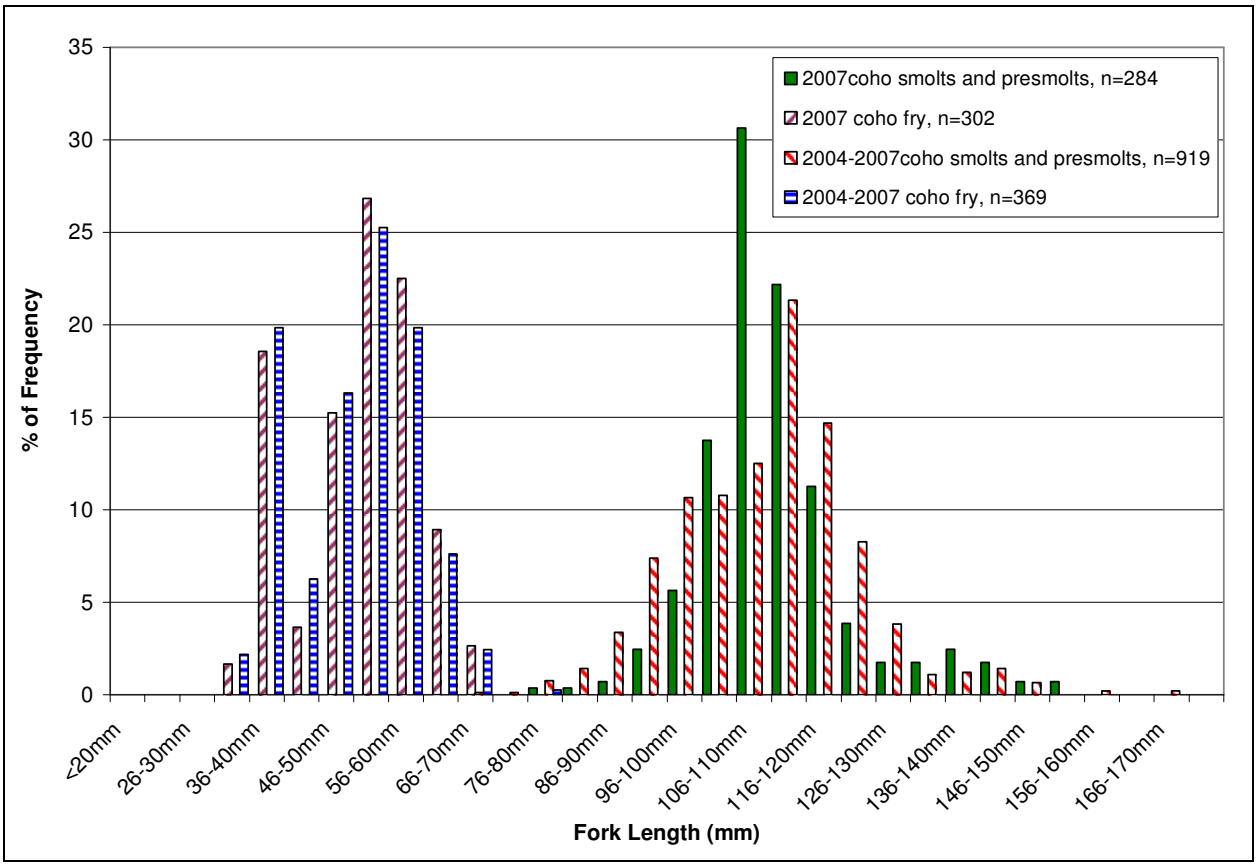


Figure 36. Coho smolt and fry fork lengths in 5 mm increments by percent of frequency for Olema Creek in year 2007 compared to the 2004-2007 average.

The coho fork lengths recorded throughout the spring monitoring efforts on Olema Creek ranged from 33mm to 169mm. The highest frequency of fork lengths for coho smolts occurred between 111mm to 115mm representing 31% of the subsample of coho. In Olema Creek, coho smolts were slightly smaller than the observed running average for all years of record (2004-2007). In comparison coho fry captures remained simlar to the observed running average.

The steelhead fork lengths recorded throughout the spring monitoring efforts on Olema Creek ranged from 22mm to 220mm. The highest frequency of fork lengths for steelhead smolts occurred between 156mm to 160mm representing 19% of the subsample of steelhead. Although

1+ steelhead captures were similar to the running average in Olema Creek, 1+ steelhead captures have been minimal throughout the trapping years. The 1+ steelhead captures in 2007 represents 80% of the 1+ steelhead total catch for all years. Similar to the coho fry observed frequencies, the steelhead fry observed frequencies were similar to the running average for all years.

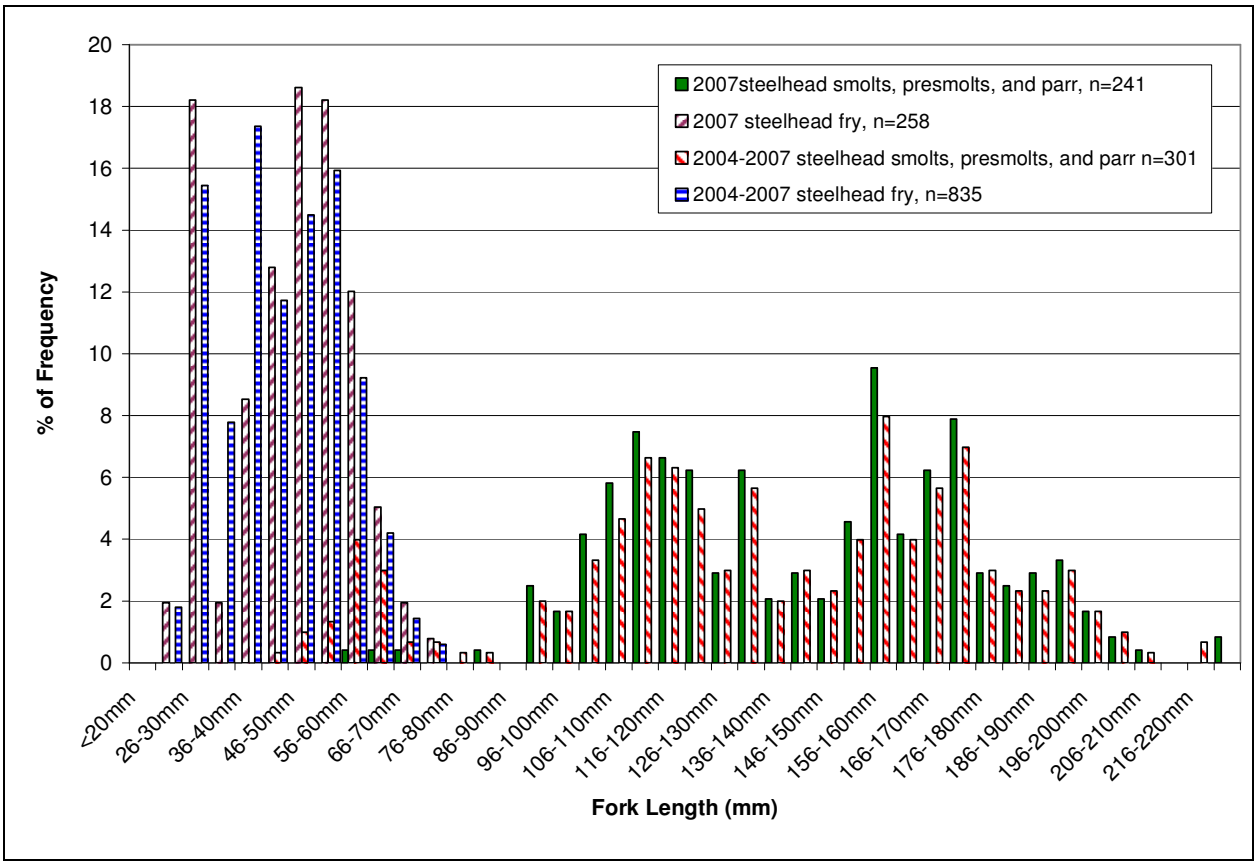


Figure 37. Steelhead smolt and fry fork lengths in 5 mm increments by percent of frequency for Olema Creek in year 2007 compared to the 2004-2007 average.

The coho fork lengths recorded throughout the spring monitoring efforts on Redwood Creek ranged from 34mm to 155mm. The highest frequency (19%) was observed in the 111-115 mm length category. In Redwood Creek coho smolts were larger than the running average which thus increases their chances of ocean survival compared to past years. Length frequencies for coho fry on Redwood Creek were shorter than the running average with 32% of the fry observed in the 36-40 mm length category.

Steelhead fork lengths on Redwood Creek ranged from 22mm to 207mm with the highest frequency (59%) occurring between 161 mm to 185 mm. In general 1+ steelhead were longer than the observed running average for all years of trapping (2005-2007). However, the composition of 1+ steelhead in 2007 was predominatly comprised of steelhead in a smolt life stage compared to the higher numbers of parr or presmolt 1+ steelhead observed in previous years.

On Pine Gulch Creek, coho fork lengths ranged from 97mm to 129mm. The peak fork length frequency of coho smolts ranged from 111mm to 115mm representing 46% of the population. There were no coho fry captured during the 2007 smolt trapping season. Steelhead fork lengths ranged from 21mm to 193mm. In Pine Gulch, the greatest frequency of fork lengths of steelhead smolts ranged from 156mm to 160mm representing 17% of the population. In general, fork length frequencies for Pine Gulch for both coho and steelhead smolts were similar to the running average for all years.

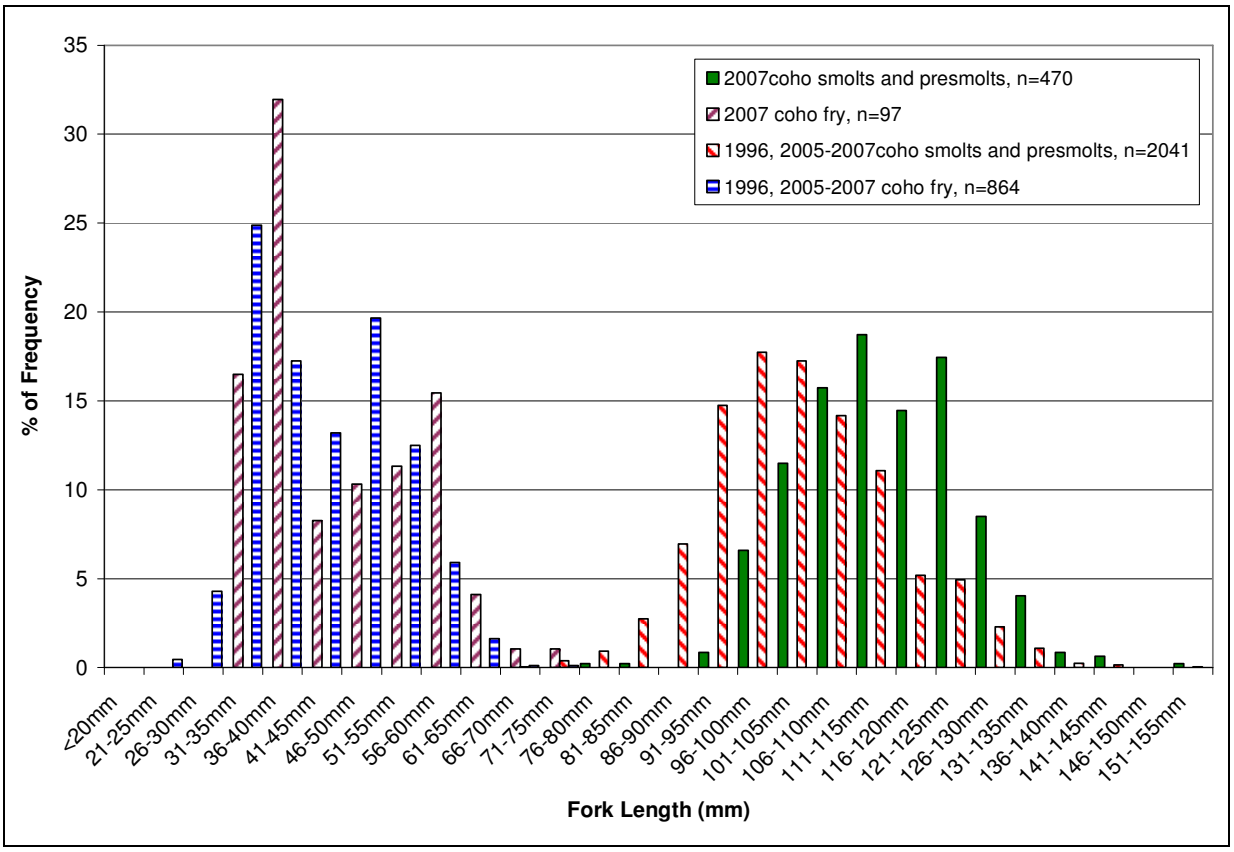


Figure 38. Coho smolt and fry fork lengths in 5 mm increments by percent of frequency for Redwood Creek in year 2007 compared to the 1996, 2005-2007 average.

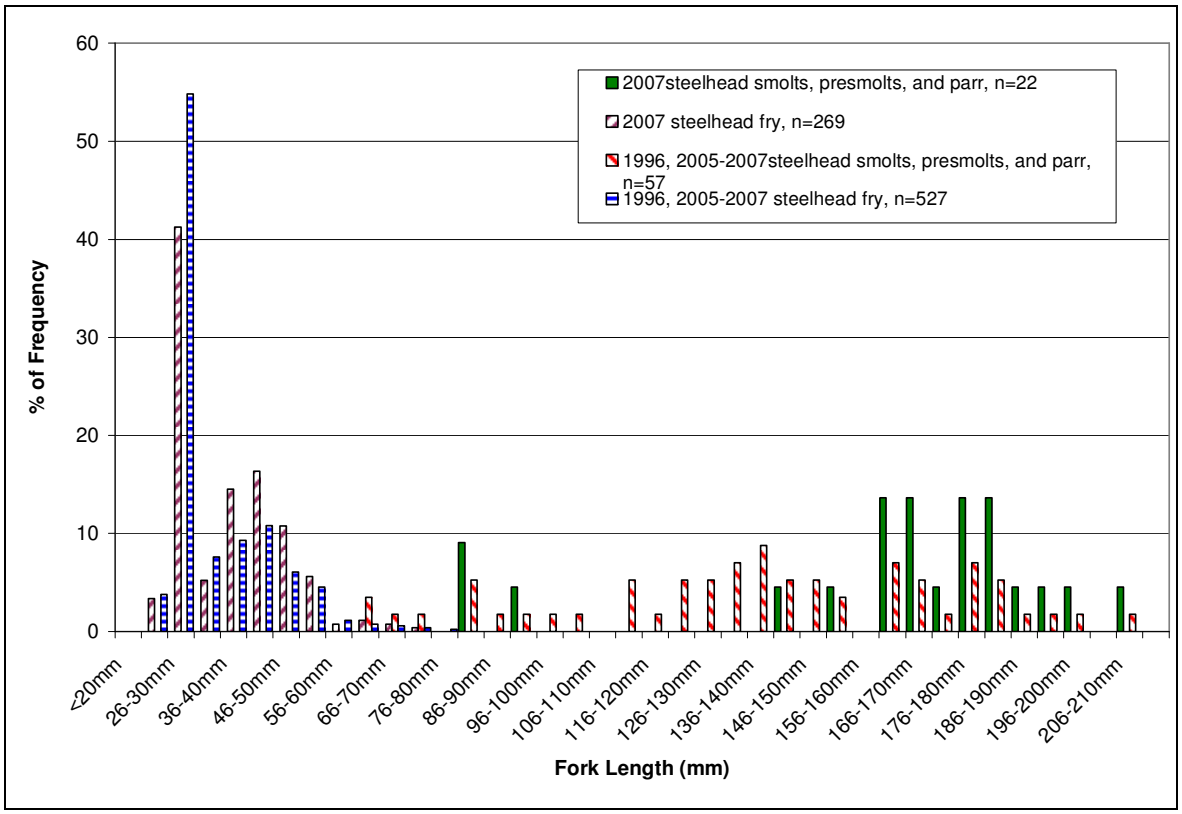


Figure 39. Steelhead smolt and fry fork lengths in 5 mm increments by percent of frequency for Redwood Creek in year 2007 compared to the 1996, 2005-2007 average.

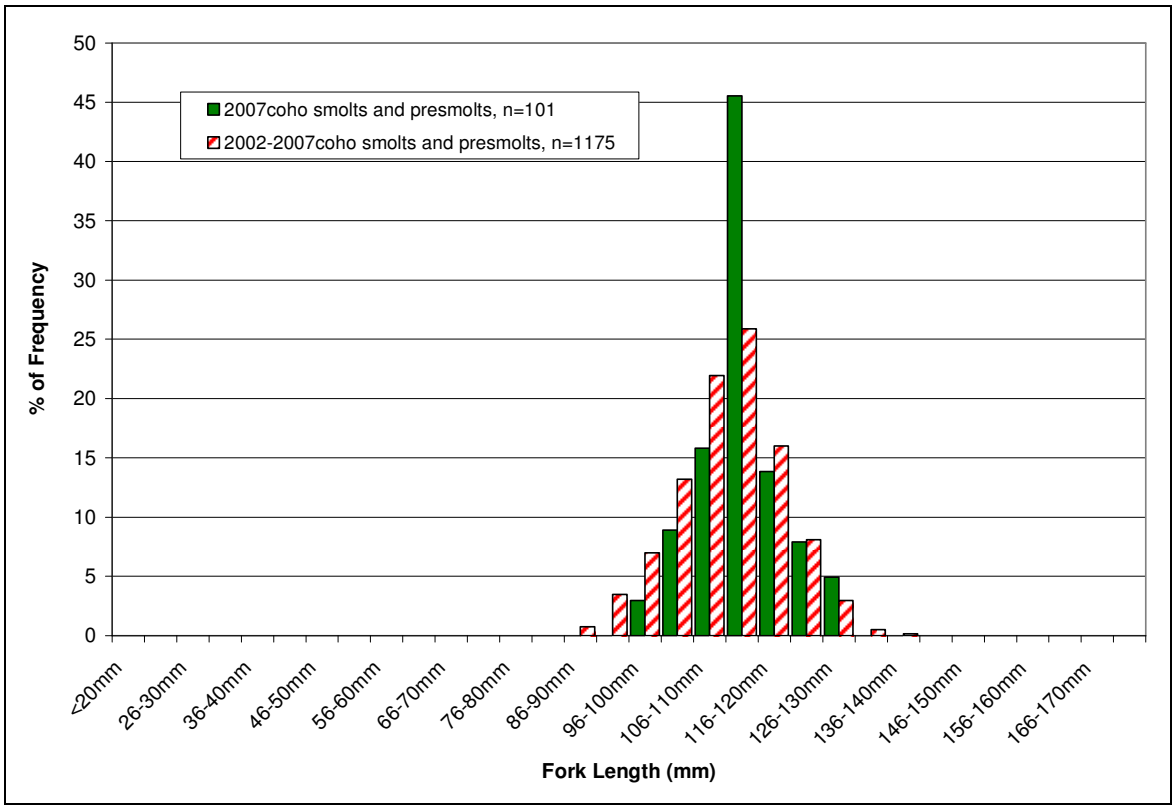


Figure 40. Coho smolt and fry fork lengths in 5 mm increments by percent of frequency for Pine Gulch Creek in year 2007 compared to the 2002-2007 average.

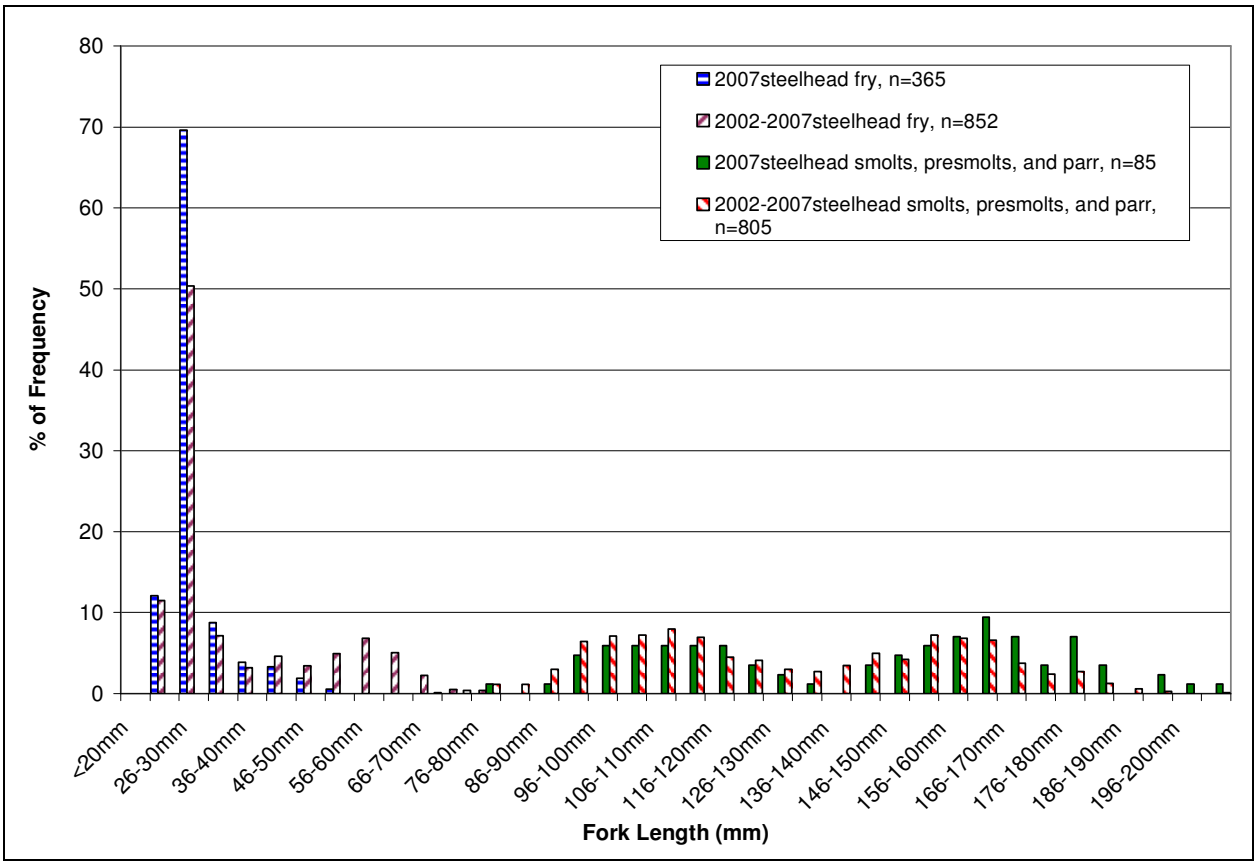


Figure 41. Steelhead smolt and fry fork lengths in 5 mm increments by percent of frequency for Pine Gulch Creek in year 2007 compared to the 2002-2007 average.

The highest fork length frequencies for coho smolts in both Pine Gulch and Redwood were observed in the 111 -115 mm length category while Olema Creek was slightly smaller with the 106 – 110 mm size category most frequently observed. While this is true for 2007, this has not been the trend for all years. When the running average is compared between all three watersheds for all years, the average coho smolt produced from Redwood Creek is approximately 10 mm shorter than the average coho smolt observed in both Olema and Pine Gulch Creeks (Figure 42).

No trends were observed when comparing the running average for steelhead between all three monitored watersheds. This could be an artifact of the various life cycle strategies of steelhead resulting in captures of multiple life stages within each trapping season. Further data analysis or recording modifications may be required to determine if variations in steelhead frequencies do exist between watersheds.

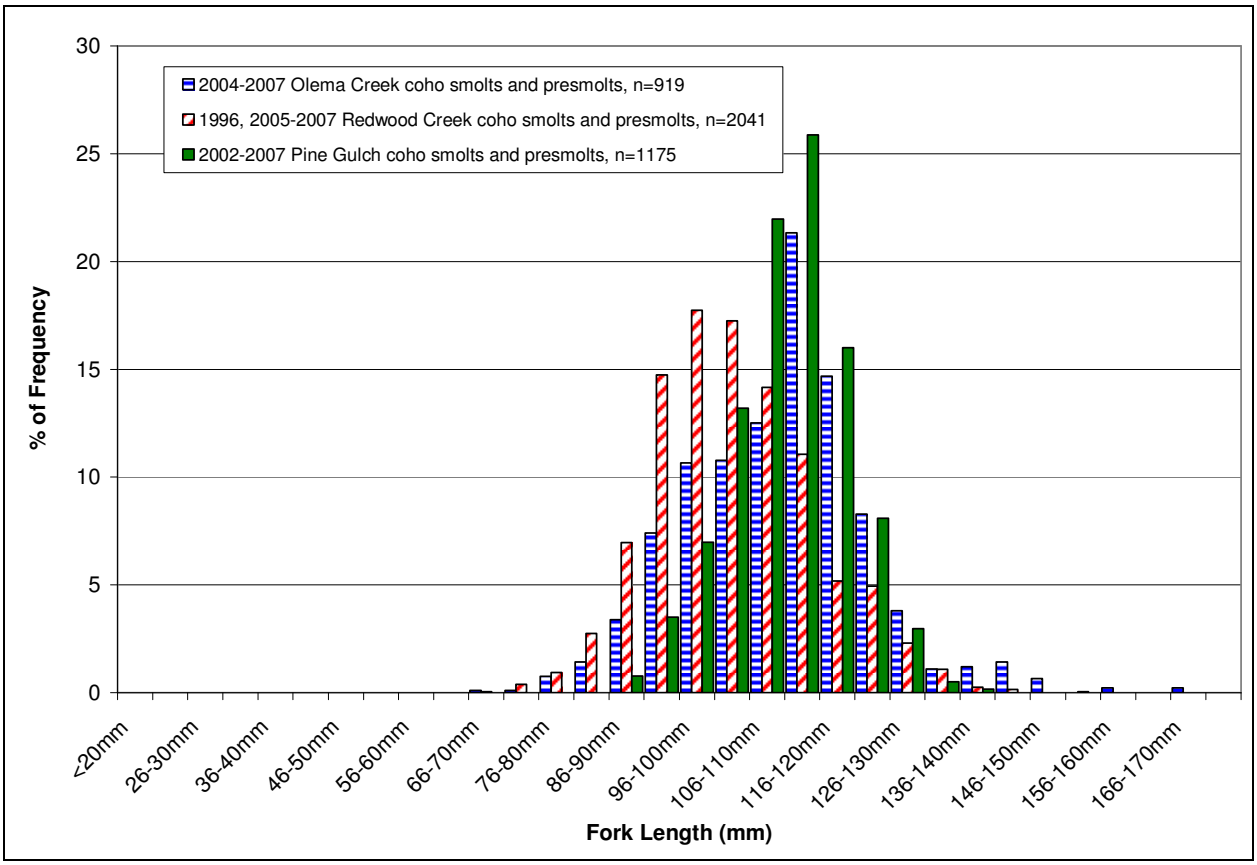


Figure 42. Coho fork lengths in 5mm increments by percent of frequency for Olema, Redwood, and Pine Gulch Creek running averages measured during smolt trap operations.

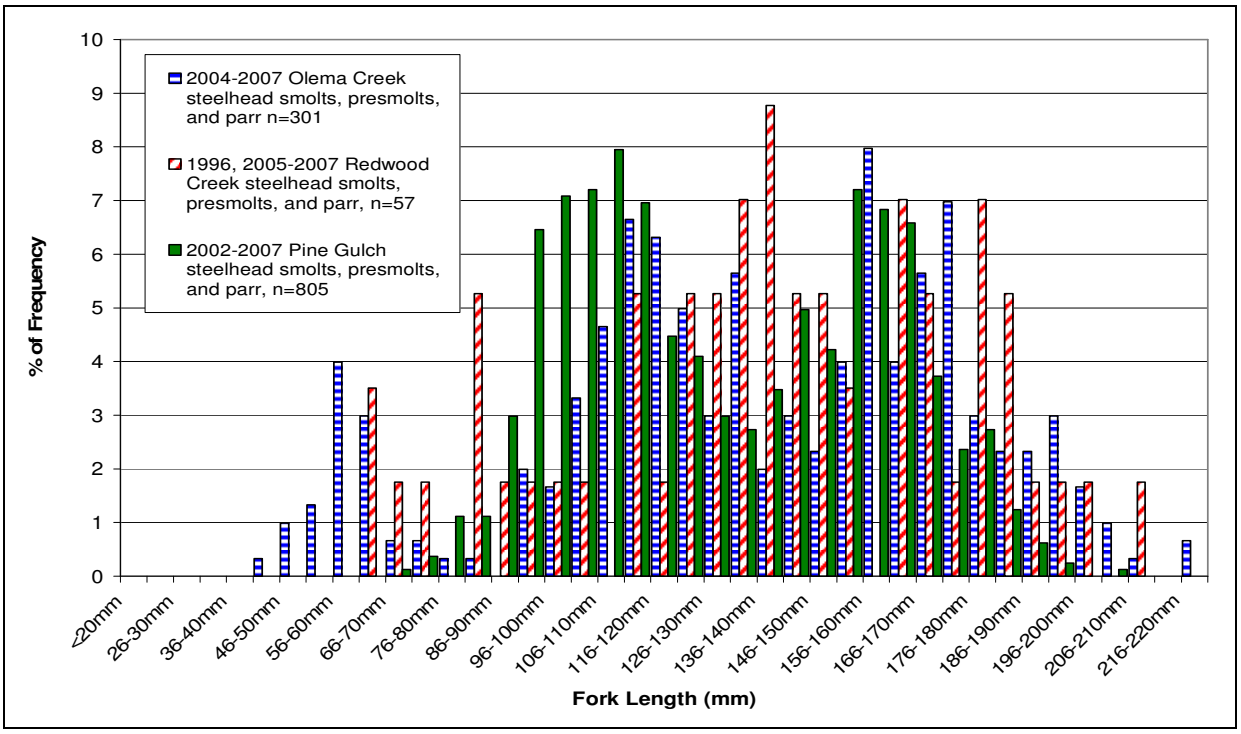


Figure 43. Steelhead fork lengths in 5mm increments by percent of frequency for Olema, Redwood, and Pine Gulch Creek running averages measured during smolt trap operations.

3.11.2 Weight-Length Relationships

Combined length and weight data provide critical information that contributes to the understanding of fish heath and condition at the time of outmigtration. Throughout the 2007 smolt trap operations, staff recorded fork lengths (FL) and weights of a subsample of fish caught in the trap. Weight-length relationships are presented for Olema Creek coho (Figure 44) and steelhead (Figure 45); Redwood Creek coho (Figure 46) and steelhead (Figure 47); and Pine Gulch coho (Figure 48) and steelhead (Figure 49). Average weight-length ralationships are also provided as a comparison between the smolt production in 2007 and the running average from all years surveyed. Such comparisons can be used to determine if seasonal or anthropogenic events caused a detrimental effect to the health of the population. A comparison of average weight-length relationships for all three watersheds for coho (Figure 50) and for steelhead (Figure 51) are provided to determine if variations in realitive health between these key populations exist.

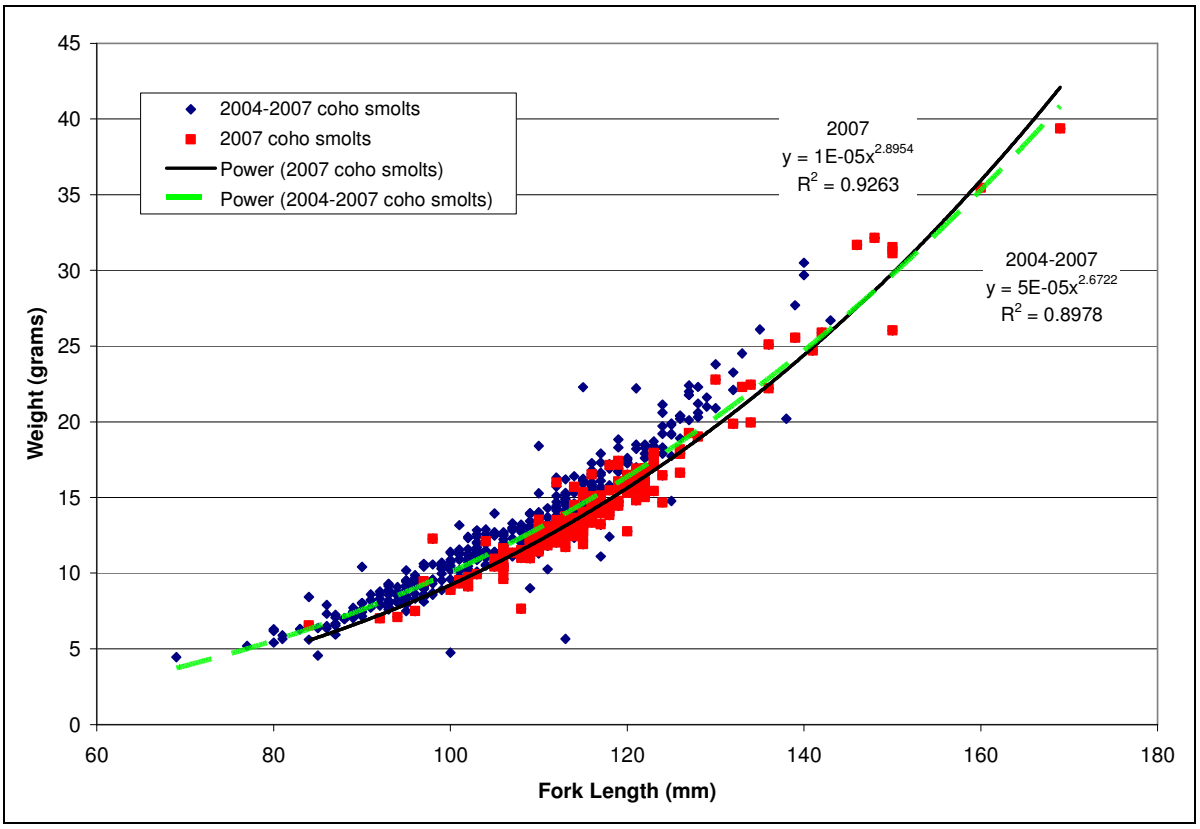


Figure 44. Weight-length comparison between coho smolts of Olema Creek in 2007 compared to the average from years 2004-2007.

Based on the comparison of the running average of weight-length for all years (2004-2007) in Olema Creek, the coho smolts outmigrating in 2007 were slightly lighter per unit length than observed in previous years. In addition, 2007 outmigrants included nine individuals exceeding 140 millimeters in length (maximum length 169 mm), perhaps suggesting outmigration of two-year olds. In the three prior years of monitoring, only four exceeded 140mm. The length-relationship for 1+ steelhead captured were similar to those observed in previous years.

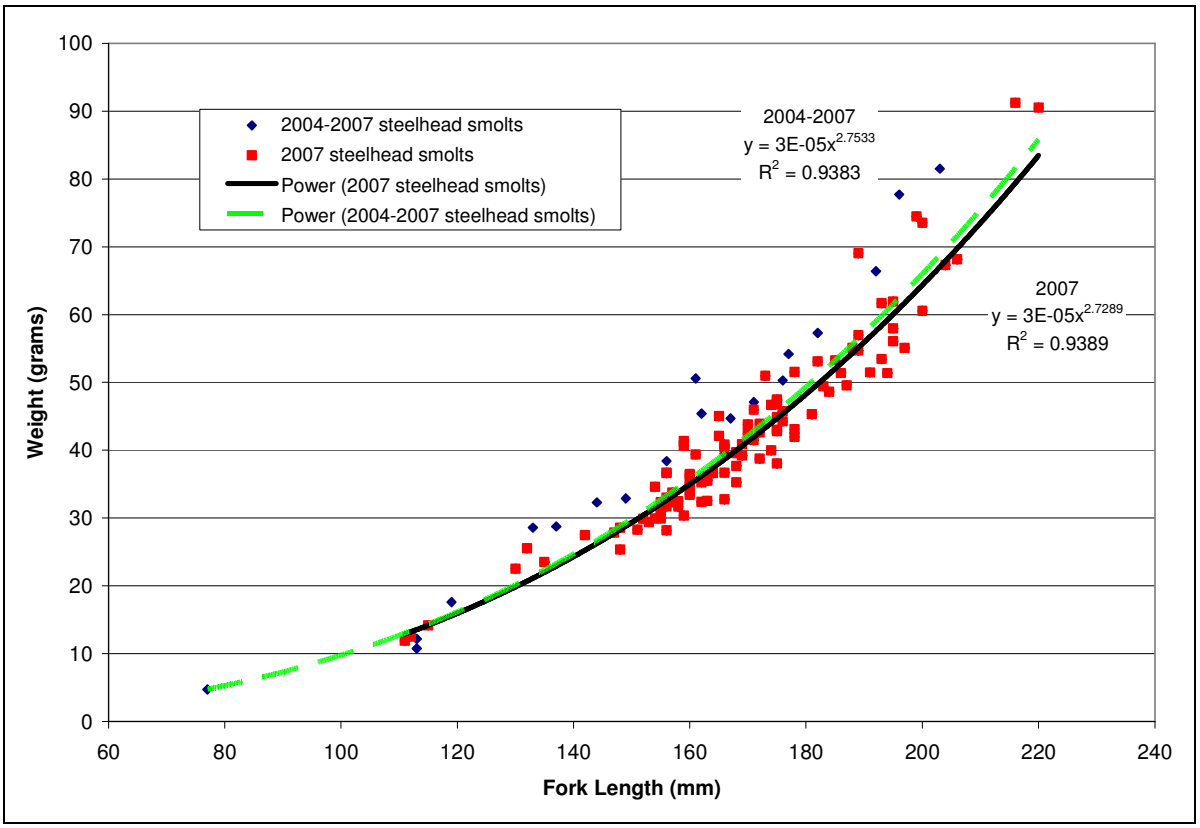


Figure 45. Weight-length comparison between steelhead smolts of Olema Creek in 2007 compared to the average from years 2004-2007.

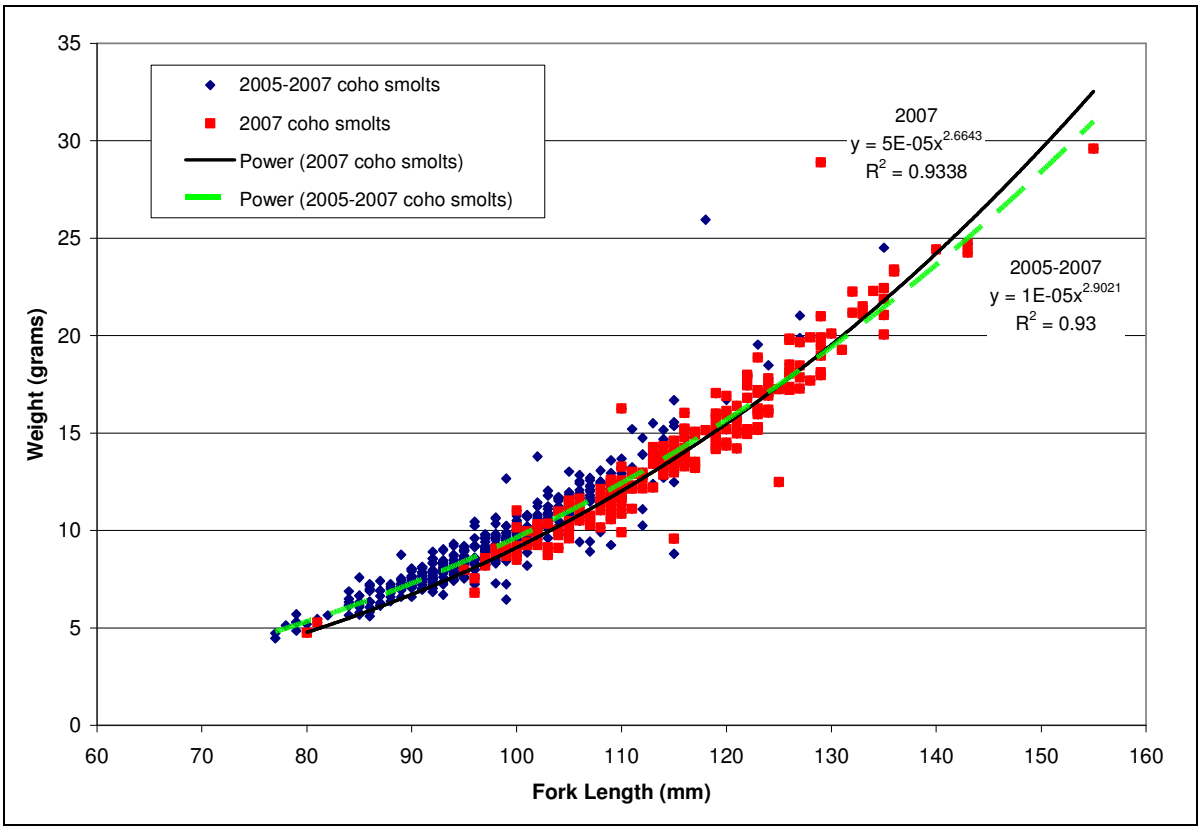


Figure 46. Weight-length comparison between coho smolts of Redwood Creek in 2007 compared to the average from years 2005-2007.

Based on the comparison of the running average of weight-length for all years (2005-2007) in Redwood Creek, the coho smolts outmigrating in 2007 had a similar weight-length index to those captured in previous years. While the length-relationship for 1+ steelhead captured were disimilar to those observed in previous years, with all 2007 outmigrants ranging in size from 150 to 200mm. Until 2007, only one steelhead smolt of this size had been observed in the Redwood Creek trap.

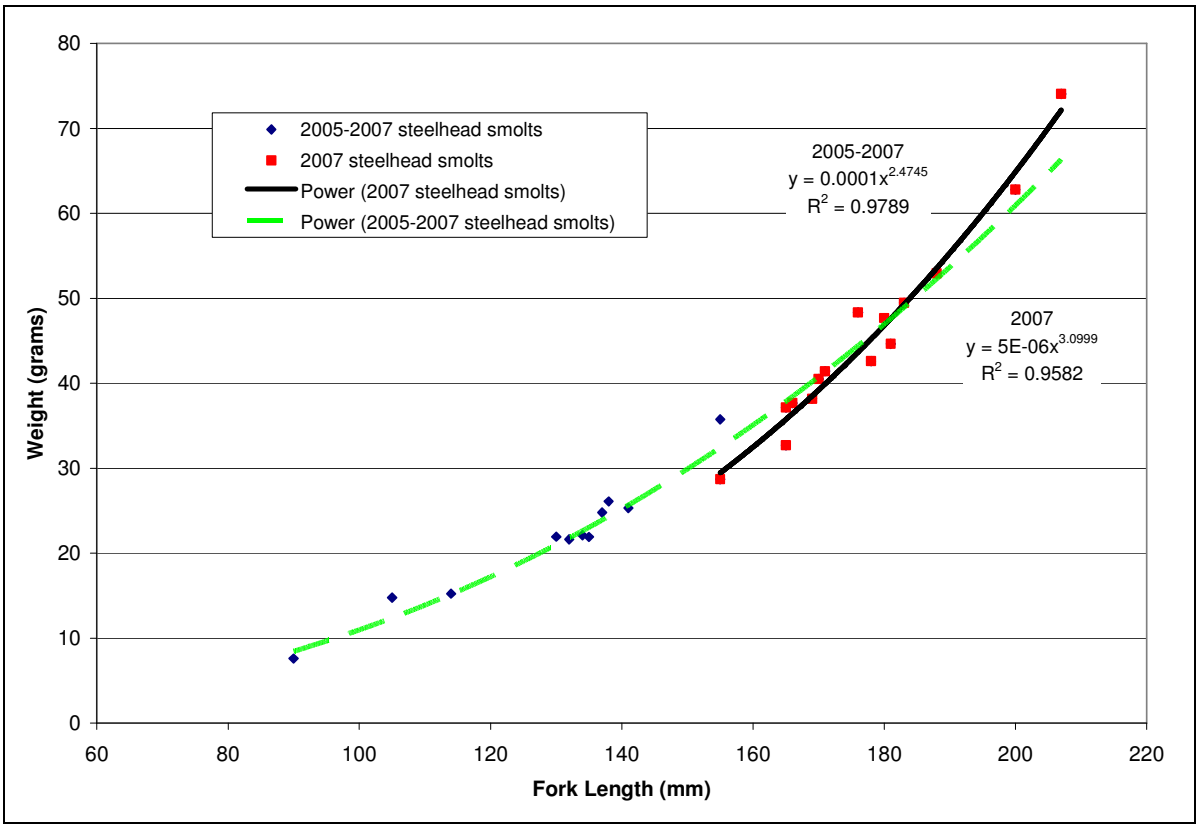


Figure 47. Weight-length comparison between steelhead smolts of Redwood Creek in 2007 compared to the average from years 2005-2007.

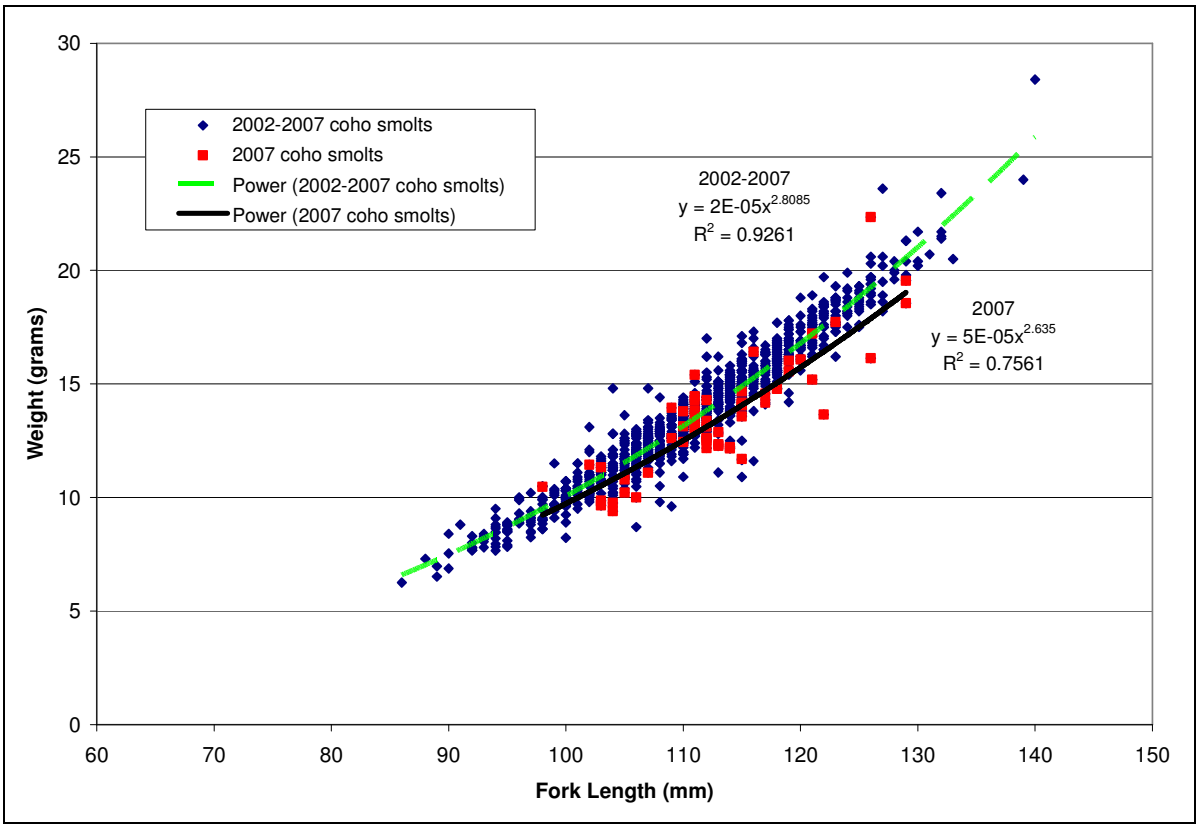


Figure 48. Weight-length comparison between coho smolts of Pine Gulch Creek in 2007 compared to the average from years 2002-2007.

Based on the comparison of the running average of weight-length for all years (2002-2007) in Pine Gulch Creek, the coho smolts outmigrating in 2007 were not as healthy as in previous years, although the R^2 value of 0.76 (all other watersheds R^2 greater than 0.89)is indicative of more variable health conditions. Like the coho smolts, the length-weight relationship for 1+ steelhead sampled in 2007 showed a lower index than the running average from all years. Again, the weight-length correlation for the steelhead is very low, with an R^2 of 0.39.

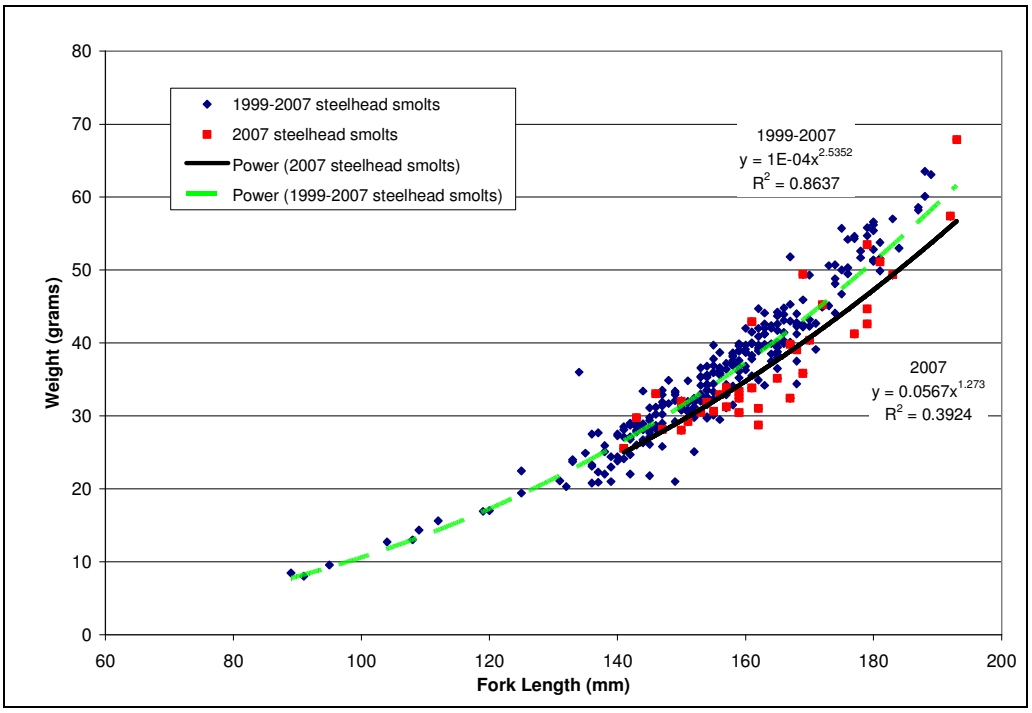


Figure 49. Weight-length comparison between steelhead smolts of Pine Gulch in 2007 compared to the average from years 2002-2007.

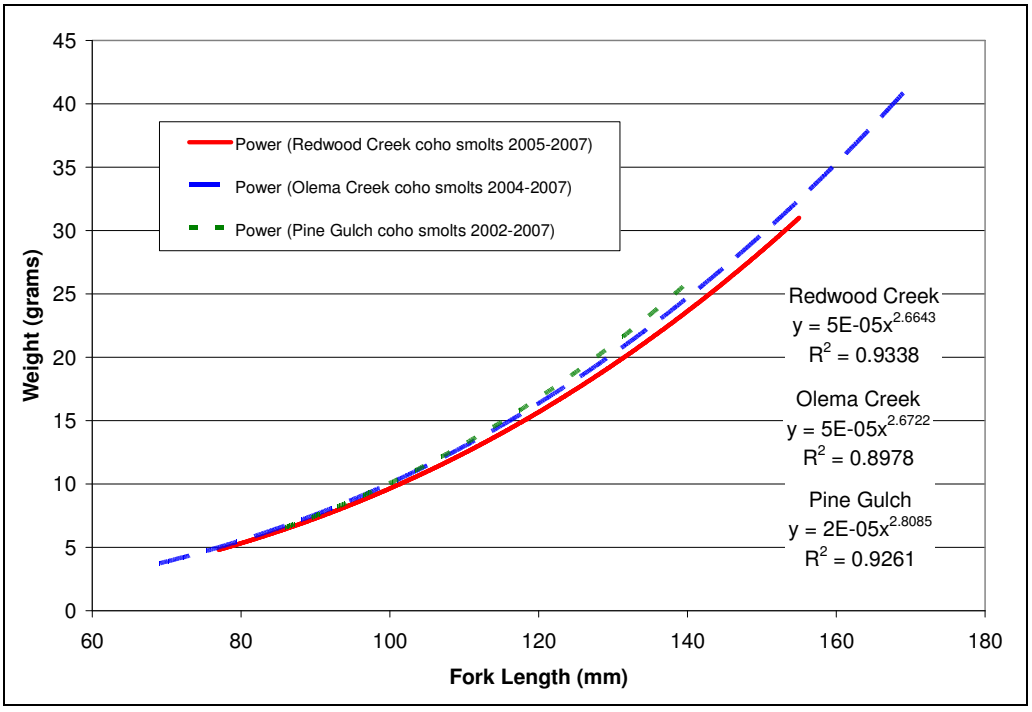


Figure 50. Weight-length comparison between coho smolt of Olema, Redwood, and Pine Gulch Creeks for all years of record.

For both coho smolts and 1+ steelhead a comparison of the running average weight-length relationship for all three watersheds indicated that the fish rearing in Pine Gulch are healthier during the outmigration period than those sampled in Olema and Redwood Creeks. Also for both coho smolts and 1+ steelhead Redwood Creek has the lowest average condition especially when comparing fish of higher lengths and weights.

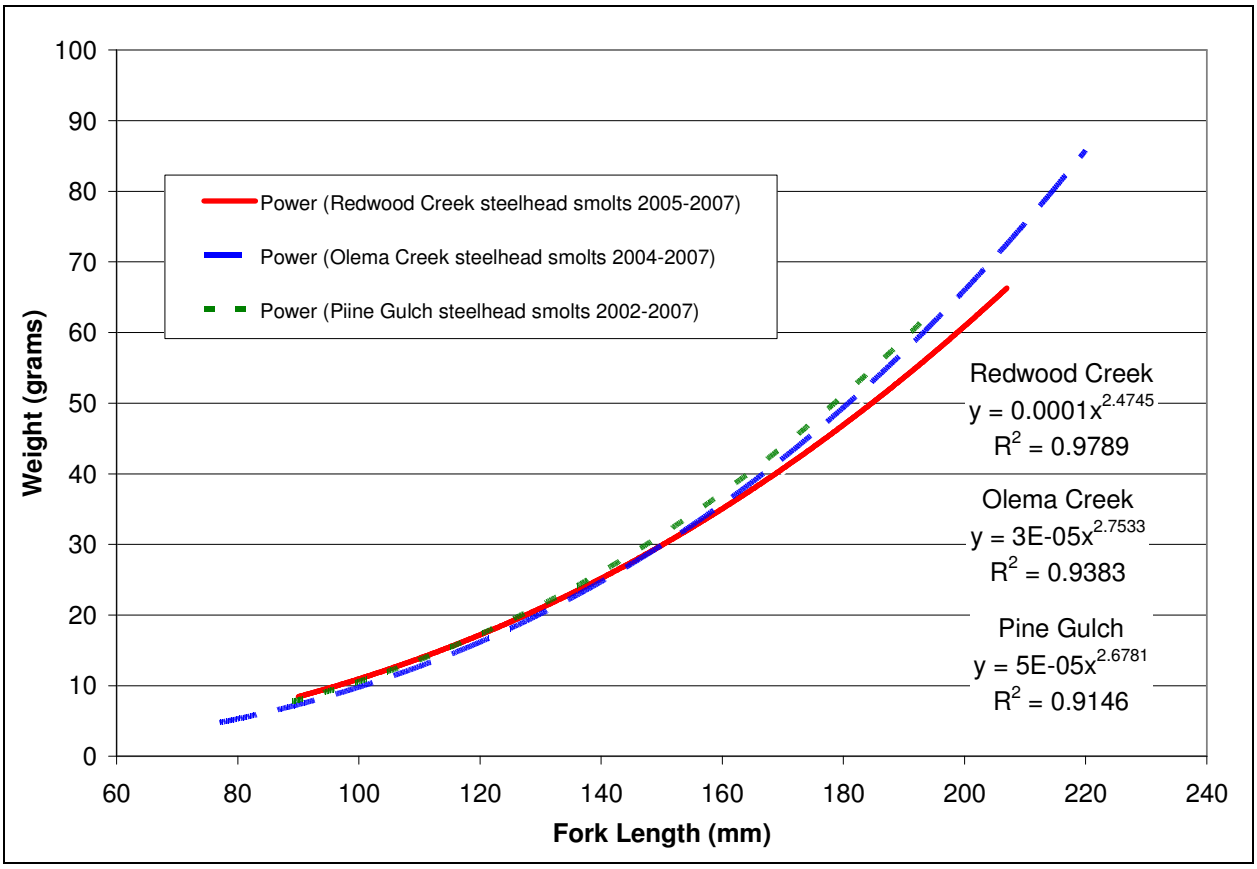


Figure 51. Weight-length comparison between steelhead smolts of Olema, Redwood, and Pine Gulch Creeks for all years of record.

3.11.3 Fulton Condition Factor

Length is the principal factor affecting the weight of fishes. In spite of this, there can be significant differences in weight distribution between similar size fish of the same species within a particular watershed and within the surrounding region. In order to compare length-weight relationships, we applied the Fulton Condition Factors (K) to establish comparable indices of condition (Murphy and Willis 1996). Condition factors are a ratio relating fish length to fish weight therefore measuring the relative biomass of a fish. Tables 27, 29, and 31 show the comparison between coho smolt length, weight, and K-factors for all years of trapping on Olema, Redwood and Pine Gulch Creeks respectively. Tables 28, 30, and 32 provide a comparison between steelhead smolt length, weight, and K-factors for all years of trapping on Olema, Redwood and Pine Gulch Creeks respectively.

The average coho smolt fork length of fish sampled at Olema, Redwood, and Pine Gulch Creeks in 2007 ranged from 112.98mm in Pine Gulch to 116.43mm in Olema Creek. The mean weight

of coho smolts ranged from 13.57g in Pine Gulch to 14.72g in Olema Creek with the mean K-factor of 0.9 in Redwood Creek, 0.91 in Olema Creek and 0.92 in Pine Gulch. Similarily, Pine Gulch also had the highest total mean K-factor (0.99) for sampled coho smolts from all years while Redwood Creek had the lowest total mean K-factor (0.96) for all sampling years.

The average steelhead smolt fork length of fish sampled at Olema, Redwood, and Pine Gulch Creeks in 2007 ranged from 161.63mm in Pine Gulch to 177.31mm in Redwood Creek. The mean weight of steelhead smolts ranged from 37.58g in Pine Gulch to 43.65g in Redwood Creek with the mean K-factor of 0.77 in Redwood Creek, 0.92 in Pine Gulch and 0.98 in Olema Creek. However, this differs from the total mean K-factor for all years in which Pine Gulch has the highest total mean K-factor at 0.99 and Olema Creek has the lowest total mean K-factor at 0.87.

Table 27. Mean and median coho smolt length, weight, K-factor, and standard deviation (SD) calculated for the trapping location at Olema Creek 2004-2007.

Year	Sample Size	Mean Length (mm)	Length SD*	Median Length (mm)	Mean Weight (g)	Weight SD	Median Weight (g)	Mean K-Factor	K-Factor SD
2004	169	114.31	9.30	113	15.11	4.02	14.5	0.99	0.08
2005	37	116.05	9.53	116	15.95	3.89	14.98	1.01	0.13
2006	203	98.94	9.56	98	10.28	3.06	9.56	1.04	0.11
2007	191	116.43	10.99	115	14.72	4.73	13.64	0.91	0.07
Total Average	**750**	**109.89**	**12.69**		**13.40**	**4.56**		**0.98**	**0.10**

Although the 2007 Olema Creek coho smolt mean length was longer than those observed in previous survey years, the mean K-factor was lower than both previous years and the total average for all years. A similar phenomenon was also observed with steelhead smolts in which the mean smolt length was the second highest on record yet the mean K-factor was the lowest on record.

Table 28. Mean and median steelhead smolt length, weight, K-factor, and standard deviation (SD) calculated for the trapping location at Olema Creek 2004-2007.

Year	Sample Size	Mean Length (mm)	Length SD*	Median Length (mm)	Mean Weight (g)	Weight SD	Median Weight (g)	Mean K-Factor	K-Factor SD
2004	11	176.55	15.38	176	55.31	14.37	50.6	0.99	0.09
2005	6	127.17	32.45	128.5	22.93	15.85	22.25	0.94	0.13
2006	3	129.67	9.45	133	24.99	6.39	28.59	1.13	0.09
2007	108	168.52	19.30	167	41.72	13.65	39.63	0.85	0.08
Total Average	**128**	**166.35**	**22.11**		**41.61**	**14.88**		**0.87**	**0.10**

Table 29. Mean and median coho smolt length, weight, K-factor, and standard deviation (SD) calculated for the trapping location at Redwood Creek 2005-2007.

Year	Sample Size	Mean Length (mm)	Length SD*	Median Length (mm)	Mean Weight (g)	Weight SD	Median Weight (g)	Mean K-factor	K-Factor SD
2005	81	100.51	8.64	99	10.58	3.09	9.75	1.02	0.11
2006	411	97.69	8.32	97	9.26	2.39	8.98	0.98	0.07
2007	213	115.28	10.91	115	14.16	4.08	13.63	0.90	0.07
Total Average	**705**	**103.31**	**12.13**		**11.01**	**4.87**		**0.98**	**0.10**

Like Olema Creek the 2007 Redwood Creek coho and steelhead smolt mean length were both longer than those observed in previous survey years. However, the mean K-factor was lower than both previous years and the total average for both species.

Table 30. Mean and median steelhead smolt smolt length, weight, K-factor, and standard deviation (SD) calculated for the trapping location at Redwood Creek 2005-2007.

Year	Sample Size	Mean Length (mm)	Length SD*	Median Length (mm)	Mean Weight (g)	Weight SD	Median Weight (g)	Mean K-Factor	K-Factor SD
2005	1	90	N/A	N/A	7.6	N/A	N/A	1.04	N/A
2006	10	132.10	13.91	134.5	22.94	5.90	22.01	0.99	0.11
2007	15	176.93	13.77	176	45.24	11.58	42.6	0.80	0.04
Total Average	**26**	**159.92**	**26.08**		**35.69**	**14.75**		**0.85**	**0.16**

Table 31. Mean and median coho smolt smolt length, weight, K-factor, and standard deviation (SD) calculated for the trapping location at Pine Gulch 1999, and 2002-2007.

Year	Sample Size	Mean Length (mm)	Length SD*	Median Length (mm)	Mean Weight (g)	Weight SD	Median Weight (g)	Mean K-Factor	K-Factor SD
1999	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2002	246	113.32	7.46	114	14.31	2.76	14.5	0.97	0.05
2003	560	111.54	7.69	111	14.03	2.74	13.8	1.00	0.05
2004	133	111.80	7.51	112	14.01	2.80	13.6	0.99	0.06
2005	2	112.5	0.71	112.5	14.33	0.28	14.33	1.01	0.04
2006	87	99.63	6.44	98	9.78	1.89	9.46	0.98	0.06
2007	57	112.98	6.67	112	13.57	2.50	13.37	0.93	0.09
Total Average	**1,085**	**111.10**	**8.22**		**13.73**	**2.93**		**0.99**	**0.06**

In Pine Gulch the mean fork length for coho smolts was slightly higher (1.88 mm) than average when compared to previous years but like Olema and Redwood Creeks the mean K-factor was the lowest on record. The Pine Gulch mean steelhead smolt fork length was the longest on record, yet the mean K-factor was the second lowest on record.

Table 32. Mean steelhead smolt smolt length, weight, K-factor, and standard deviation (SD) calculated for the trapping location at Pine Gulch 1999, and 2002-2007.

Year	Sample Size	Mean Length (mm)	Length SD*	Median Length (mm)	Mean Weight (g)	Weight SD	Median Weight (g)	Mean K-Factor	K-Factor SD
1999	41	155.46	14.39	155	34.02	10.05	32.4	0.88	0.05
2002	7	156.57	17.40	159	38.1	11.75	39.6	0.96	0.04
2003	185	157.68	12.42	157	36.89	8.69	36.3	0.93	0.08
2004	40	154.9	13.31	155	36.39	8.89	35.35	0.96	0.07
2005	8	109	19.76	106	15.58	9.10	12.85	1.11	0.05
2006	2	137	39.60	137	26.88	17.73	26.88	0.99	0.16
2007	37	161.97	16.63	161	37.58	9.42	33.81	0.92	0.47
Total Average	**320**	**156.35**	**15.54**		**35.97**	**9.69**		**0.93**	**0.17**

3.12 Smolt Trap Summary of Non-salmonid Total Catch

An annual summary of total catch for non-salmonid species is represented in Table 33. In 2005, 2006, and 2007, no non-native species were trapped in both Olema and Redwood Creeks. While Pine Gulch has only captured an average of eight non-native fish (green sunfish) per year representing less than 1% of the total non-salmonid catch. On Olema Creek, California Roach represented 66% of the total non-salmonid capture in 2007 which was almost three times higher than the average seasonal roach capture. On Redwood Creek only 150 non-salmonids were captured in 2007 which is the lowest number since trapping was initiated in 2005. In contrast Pine Gulch had the highest number of non-salmonids captured since trapping was initiated in 1999 with above average captures of both lamprey and sculpin.

Table 33. Summary of non-salmonid information for Olema, Redwood, and Pine Gulch Creeks trap operations, 1999-2007.

Watershed	Year	Trap Dates From	To	CH	GSF	GSH	LAM	PL	RO	SCU	STK	SUC	Totals
Olema	2004	30-Mar	28-May	2	1	1	15	0	274	243	3,083	144	3,763
Creek	2005	1-Apr	9-May	0	0	0	33	0	1,006	117	648	58	1,862
	2006	10-Apr	9-Jun	0	0	0	5	1	420	644	2,998	3	4,071
	2007	15-Mar	26-May	0	0	0	35	0	3,190	364	1,110	140	4,839
Total Average				**>1**	**>1**	**>1**	**22**	**>1**	**1,223**	**342**	**1,956**	**86**	**3,634**
Redwood	2005	27-Mar	31-May	0	0	0	0	0	0	24	5,343	0	5,367
Creek	2006	18-Apr	9-Jun	0	0	0	0	0	0	133	117	0	250
	2007	18-Mar	26-May	0	0	0	0	0	0	93	57	0	150
Total Average				**0**	**0**	**0**	**0**	**0**	**0**	**83**	**1,839**	**0**	**1,922**
Pine Gulch	1999	16-Apr	24-May	0	0	0	5	0	18	43	4	52	122
	2002	28-Mar	29-May	0	15	0	2	0	11	94	6	0	128
	2003	28-Mar	30-May	0	10	0	4	0	0	99	9	1	123
	2004	25-Mar	28-May	0	1	0	2	0	0	101	47	0	151
	2005	31-Mar	31-May	0	22	0	7	0	1	83	43	0	156
	2006	26-Apr	9-Jun	0	2	0	2	0	0	149	9	0	162
	2007	15-Mar	26-May	0	3	0	46	0	0	193	69	1	312
Total Average				**0**	**8**	**0**	**10**	**0**	**4**	**109**	**27**	**8**	**165**

Species Code: CH = Chinook Salmon; GSF = Green Sunfish (non-native); GSH = Golden Shiner (non-native); LAM = Lamprey spp.; PL = Pacific Lamprey; RO = California Roach; SCU = Sculpin spp.; STK = Threespine Stickleback; SUC = Sacramento Sucker.

3.13 Olema Creek Index Reach Monitoring Summary

Index reach monitoring was initiated at seven sites on Olema Creek in 1999. In 2000, Index Reach 8 was added to represent the intermittent portion of the upper mainstem. The stream kilometer (km) location of each index reach is presented in Table 34 and are shown in Figure 3, page 13. In 2007, seven of the eight index reaches on the mainstem of Olema Creek were sampled. Also, in spring 2007, we initiated equiprobable general systematic sampling (GSS) using habitat surveys and electrofishing of systematically drawn pool units to estimate juvenile population and distribution on John West Fork and Quarry Gulch (See Appendix B for full results of GSS estimates). For detailed results at each location, please refer to Del Real et al. 2008.

Table 34. Site location and number for Olema Creek index reach sites.

Index site	Name/Location	Location stream km
1*	Lower Stewarts Pasture/ Olema Flat	1.2
2	Vedanta	3.7
3	Cemetery Pond/Upper Stewart's Pasture	4.9
4	Truttman	6.3
5	Bldg 168/Shook's house	7.6
6	Horse Camp	9.4
7	5 Brooks	10.8
8	Lime Kilns/Upper Olema	13.0

*not surveyed in 2007

3.13.1 Index Reach Habitat and Total Catch

The results presented in Table 35 represent the real catch documented through electrofishing activities, as well as salmonid sample size variation between reaches for sample years 1999 through 2007. Total catch is not used for any additional calculations in this report unless otherwise noted. Where multiple passes are used to sample a habitat unit, *Microfish* (maximum likelihood model) is used to calculate fish population estimates and confidence intervals by species/age class. Salmonid density results are determined based upon the habitat information described in the next section and the estimated populations determined from the multiple pass depletion method.

Table 35. Summary of total catch by species within Olema Creek mainstem index reach sample locations between 1999 and 2007; shows variation between years and distribution within watershed.

Year	Species	Index reach								Total
		1	2	3	4	5	6	7	8	
1999	CO	4	25	23	36	15	51	62	NS*	216
	SH YOY	65	222	200	341	220	159	192		1,399
	SH 1+	17	19	27	39	46	31	17		196
2000	CO	1	64	21	140	34	76	23	0	359
	SH YOY	99	342	376	232	256	190	168	209	1,872
	SH 1+	24	19	11	24	22	12	19	6	137
2001	CO	39	23	73	257	213	205	241	156	1,207
	SH YOY	22	132	202	151	354	40	30	20	951
	SH 1+	15	26	17	37	34	29	26	7	191
2002	CO	3	114	123	NS*	260	323	332	310	1,465
	SH YOY	26	102	439		267	118	139	203	1,294
	SH 1+	7	7	9		16	7	5	0	51
2003	CO	NS*	22	5	60	210	152	202	72	723
	SH YOY		35	111	26	134	139	136	79	660
	SH 1+		8	7	11	27	21	9	9	92
2004	CO	NS*	186	347	NS*	295	239	175	164	1,406
	SH YOY		146	230		182	44	20	39	661
	SH 1+		6	10		26	24	10	8	84
2005	CO	NS*	73	255	NS*	269	361	191	186	1,335
	SH YOY		42	97		180	67	38	44	468
	SH 1+		10	5		13	15	7	7	57
2006	CO	NS*	48	18	0	4	2	9	18	99
	SH YOY		28	43	93	80	65	37	43	389
	SH 1+		19	36	25	54	32	6	20	192
2007	CO	NS*	123	170	233	332	217	156	160	1,391
	SH YOY		112	135	241	120	51	10	36	705
	SH 1+		9	22	16	19	15	3	8	92

*Not sampled.

In 2007, all index reaches included the presence of coho and steelhead. Other aquatic species sampled at each index reach are documented.

Index Reach 1: Not Sampled.

Index Reach 2: is located just upstream of the Vivekananda Bridge (Vedanta Retreat) near the town of Olema at stream km 3.7. This reach is representative of the deep incised but stable channel conditions occurring between the Bear Valley Road Bridge (km 2.6) and Olema Cemetery (km 4.3). Reach two consisted of two habitat units, both pool units. In previous years, pool units have varied from between 47% of available habitat to 64%, with flatwater usually making up the majority of the remaining habitat. Riffle habitat fluctuated between 0% and 35%. Also present in Index 2 were ammocetes, roach, sticklebacks, sculpins, suckers and crayfish.

Index Reach 3: is located near stream km 4.9. This reach is fenced away from a heavily grazed field on the right bank and varies greatly in canopy cover. The riparian habitat is primarily hardwood including alder and bay trees. Reach three consisted of two habitat units, including one pool unit and one riffle unit. Pool units made up 93.5% of the total length. In previous years, pool units have composed between 22% and 100%, with flatwater generally making up the

remainder of the available habitat. Also present in Index 3 were ammocetes, roach, sticklebacks, sculpins, suckers and crayfish.

Index Reach 4: is the most remote area, below the Truttman house at stream km 6.3. It was sampled for the first time in several years in 2007 and consisted of six habitat units, including three pool units, two riffle units, and one flatwater unit. Pool units made up 70.7% of the total length. Also present in Index 4 were ammocetes, roach, sticklebacks, sculpins and suckers.

Index Reach 5: is located at stream km 7.6 near Park Residence 168. A total of four habitat units were sampled, including three pool units and one riffle unit. Pool units made up 93.3% of the total length. In previous years, pool units have made up between 72% and 83% of available habitat. Also present in Index 5 were ammocetes, roach, sticklebacks, suckers, sculpins and crayfish.

Index Reach 6: is located near stream km 9.4 adjacent to the Stewart Horse Ranch pasture. This reach represents stable hardwood dominated habitat near active spawning areas. The fencing on the east side of the creek was recently moved back to 100 ft from the bank in order to allow for growth of a wider riparian zone (CDFG Grant P0030446). Reach 6 contained a total of five habitat units, including three pool units and two riffle units. Pool units made up 79.8% of the total length. In previous years, poolu units have made up between 63% and 71% of available habitat units. Also present in Index 6 were ammocetes, roach, sticklebacks, sculpins and a salamander.

Index Reach 7: is located near stream km 10.8, between the confluences of Giacomini Gulch and John West Fork within the Five Brooks area. The reach contained a total of three habitat units, including two pool units and one riffle unit. Pool units made up 74.1% of the total length. In previous years, pool units made up between 81% and 97% of available habitat. Also present in Index 7 were sticklebacks and sculpins.

Index Reach 8: is located near stream km 13.0 and represents the intermittent channel habitat conditions of upper Olema Creek. A total of three habitat units were sampled, including two pool units and one flatwater unit. Pool units made up 94.2% of the total length. In previous years, pool units have made up between 80% and 100% of available habitat, although there have been dry units present within the index during at least one year. Also present in Index 8 were sculpins.

Figure 52 shows a comparison of habitat composition between the index reaches, and between the 2007 surveys and the averages of previous years. Five of the eight index reaches had a higher than average percentage of pool habitat, ranging from 2.9% higher (Index 8) to 29.4% higher (Index 2).

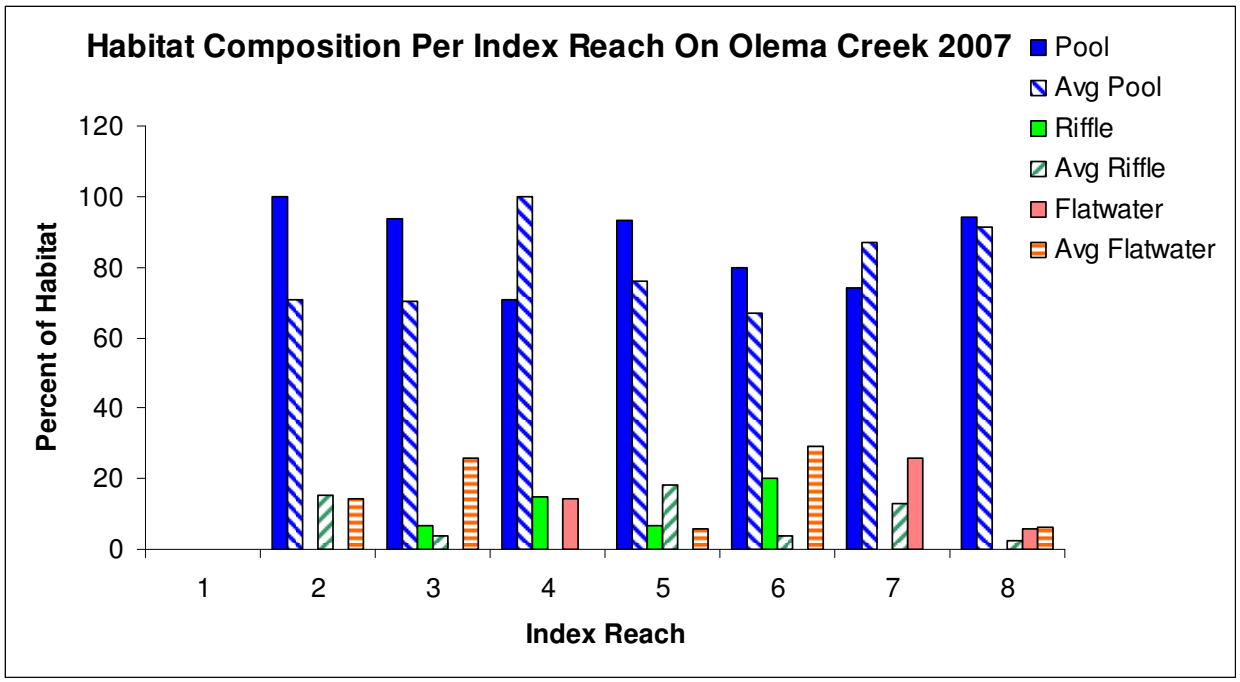


Figure 52. Comparison of habitat makeup for the different index reaches. Also shown are the cumulative average percentages of each unit type for survey years 2004-2006.

3.13.2 Salmonid Density by Habitat Type

The results of our monitoring efforts show distinct differences in salmonid numbers and densities based on habitat type. Table 36 is a summary of coho salmon population and density estimates by habitat unit taken from the electrofishing surveys performed between 1999 and 2007. The results show distinct use of pools by coho; in 2007, there were fish densities of 4.01 (±0.32) fish/meter and 0.97 (±0.08) fish/meter^2 occurring in pool habitat.

Table 36. Summary of population and density estimates from electrofishing surveys for coho salmon by habitat unit on Olema Creek, 1999-2007.

Year	Habitat Type	No. Habitat Units	Population Estimate		Density			
			No. Fish	95% CI	Fish/m	95% CI	Fish/m^2	95% CI
1999	Pool	16	**139	±17	0.33	±0.04	0.08	±0.01
	Riffle	6	**0	N/A	0	N/A	0	N/A
	Flatwater	1	**0	N/A	0	N/A	0	N/A
2000	Pool	25	382	±75	1.88	±0.37	0.52	±0.10
	Riffle	9	0	N/A	0	N/A	0	N/A
	Flatwater	3	1	±0	0.02	±0.00	0.01	±0.00
2001	Pool	25	1,127	±98	2.50	±0.22	0.62	±0.05
	Riffle	6	14	±1	0.18	±0.02	0.08	±0.01
	Flatwater	7	142	±29	1.06	±0.22	0.27	±0.05
2002	Pool	25	1,321	±99	4.58	±0.34	1.24	±0.09
	Riffle	6	12	±1	0.13	±0.01	0.04	±0.01
	Flatwater	7	211	±41	1.15	±0.22	0.29	±0.06
2003	Pool	16	722	±110	1.97	±0.30	0.49	±0.07
	Riffle	5	4	±2	0.09	±0.04	0.02	±0.01
	Flatwater	6	44	±5	0.30	±0.04	0.06	±0.01
2004	Pool	14	1,243	±206	4.26	±0.71	0.89	±0.15
	Riffle	5						
	Flatwater	5	399	±59	2.94	±0.43	0.58	±0.08
2005	Pool	11	1,429	±121	3.99	±0.34	0.78	±0.07
	Riffle	4	3	±39	0.05	±0.65	0.01	±0.13
	Flatwater	2	1	±17	0.04	±0.69	0.02	±0.30
2006	Pool	10	103	±55	0.33	±0.18	0.07	±0.04
	Riffle	3	0	N/A	0	N/A	0	N/A
	Flatwater	4	0	N/A	0	N/A	0	N/A
2007	Pool	16	1,452	±116	4.01	±0.32	0.97	±0.08
	Riffle	6	3	±31	0.09	±0.98	0.04	±0.38
	Flatwater	3	10	±13	0.52	±0.70	0.14	±0.19

*Riffles were not surveyed in 2004 due to low flow conditions.
**Population estimate does not include total catch from index 5 and 7.

Table 37. Summary of average density estimates from electrofishing surveys in all habitat units (pool, riffle, flatwater) for coho salmon in Olema Creek, 1999-2007.

Year	No. Habitat Units	Density			
		Fish/m	95% CI	Fish/m^2	95% CI
1999	23	0.30	±0.03	0.08	±0.01
2000	37	0.54	±0.11	0.14	±0.03
2001	38	1.68	±0.16	0.44	±0.04
2002	38	2.17	±0.22	0.59	±0.06
2003	27	1.29	±0.21	0.30	±0.05
2004	24	3.84	±0.62	0.79	±0.13
2005	17	3.24	±0.40	0.66	±0.80
2006	17	0.27	±0.27	0.06	±0.06
2007	25	3.56	±0.39	0.89	±0.10

Figure 53 shows a visual representation of coho salmon density based on habitat type. The data, taken from 1999 through 2007, show a marked preference by coho for pool habitat, with 2-4 fish per meter. Flatwater habitat rarely has densities higher than 1.0 fish per meter. Riffle habitat was almost never used by coho juveniles during the surveys.

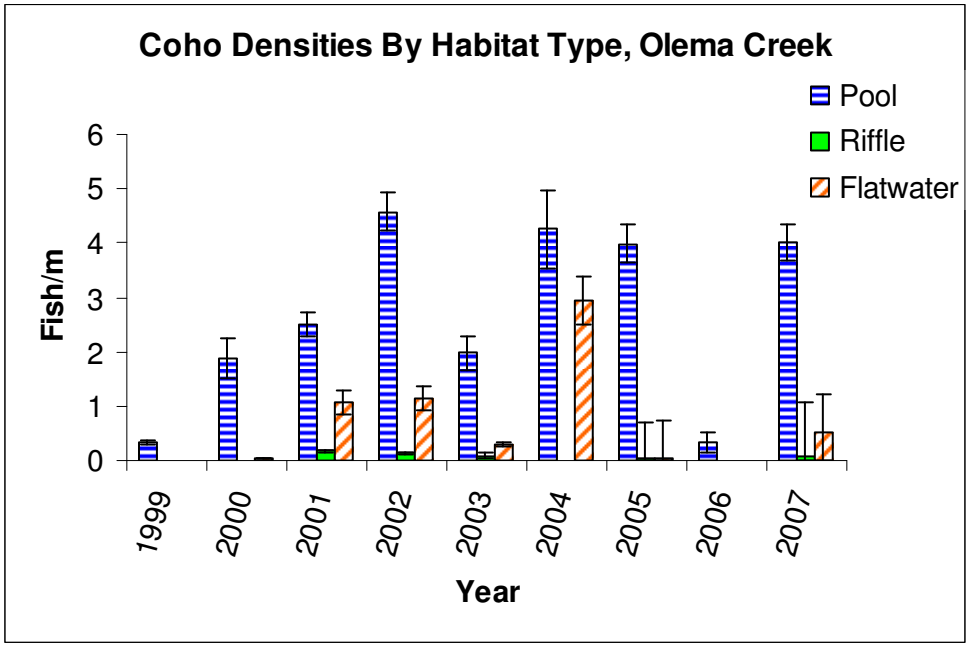


Figure 53. Average coho densities by habitat type on Olema Creek, 1999-2007.

Table 38 shows a summary of densities of steelhead young-of-year per habitat type for years 1999 through 2007. Steelhead young-of-year were found in all habitats; in 2007, the highest densities were observed in riffle habitat, 7.25 (±1.10) fish/meter compared to 1.39 (±0.23) fish/meter observed in pool habitat. This may be indicative of high coho densities in pool habitat during the summer of 2007. Because steelhead are less discriminating about depth as a feature of

habitat choice, they tend to occur in most stream habitat, even at very shallow depths. This is reasonable considering the differences between pool and riffle are depth and velocity. It should also be noted that SH 1+ confidence intervals for densities in pools and riffles (none were observed in flatwater habitat in 2007) exceed estimated number of fish. As a result, these numbers should not be used for further assessment.

Table 38. Summary of population and density estimates from electrofishing surveys for steelhead YOY by habitat unit on Olema Creek, 1999-2007.

Year	Habitat Type	No. Habitat Units	Population Estimate		Density			
			No. fish	95% CI	Fish/m	95% CI	Fish/m^2	95% CI
1999	Pool	16	**973	±60	2.31	±0.14	0.55	±0.03
	Riffle	6	**40	±19	0.59	±0.28	0.24	±0.11
	Flatwater	1	**5	±3	0.30	±0.16	0.13	±0.07
2000	Pool	25	1552	±150	7.63	±0.74	2.12	±0.21
	Riffle	9	207	±33	1.33	±0.21	0.32	±0.05
	Flatwater	3	198	±6	4.20	±0.14	1.60	±0.05
2001	Pool	25	577	±77	1.28	±0.17	0.32	±0.04
	Riffle	6	109	±21	1.41	±0.28	0.65	±0.13
	Flatwater	7	309	±34	2.30	±0.25	0.58	±0.06
2002	Pool	25	773	±110	2.68	±0.38	0.73	±0.10
	Riffle	6	73	±22	0.81	±0.24	0.27	±0.08
	Flatwater	7	506	±24	2.76	±0.13	0.69	±0.03
2003	Pool	16	504	±69	1.37	±0.19	0.34	±0.05
	Riffle	5	12	±11	0.27	±0.24	0.07	±0.06
	Flatwater	6	165	±13	1.28	±0.10	0.24	±0.02
2004	Pool	14	402	±97	1.38	±0.33	0.29	±0.07
	Riffle	5						
	Flatwater	5	325	±41	2.39	±0.30	0.47	±0.06
2005	Pool	11	436	±55	1.22	±0.15	0.24	±0.03
	Riffle	4	51	±7	0.85	±0.12	0.17	±0.02
	Flatwater	2	2	±14	0.08	±0.56	0.04	±0.25
2006	Pool	10	376	±89	1.20	±0.28	0.25	±0.06
	Riffle	3	2	±19	0.12	±1.16	0.05	±0.50
	Flatwater	4	46	±18	0.89	±0.35	0.22	±0.09
2007	Pool	16	501	±84	1.39	±0.23	0.34	±0.06
	Riffle	6	229	±35	7.25	±1.10	2.81	±0.42
	Flatwater	3	30	±8	1.57	±0.41	0.43	±0.11

*Riffles were not surveyed in 2004 due to low flow conditions.
**Population estimate does not include total catch from index 5 and 7.

Table 39. Summary of average density estimates from electrofishing surveys for steelhead YOY in all habitat units (pool, riffle, flatwater) on Olema Creek, 1999-2007.

Year	No. Habitat Units	Density			
		Fish/m	95% CI	Fish/m^2	95% CI
1999	23	1.97	±0.13	0.52	±0.04
2000	37	2.46	±0.26	0.64	±0.07
2001	38	1.47	±0.19	0.39	±0.05
2002	38	1.98	±0.17	0.53	±0.05
2003	27	1.11	±0.16	0.26	±0.04
2004	24	1.70	±0.32	0.35	±0.07
2005	17	1.11	±0.17	0.22	±0.03
2006	17	1.11	±0.33	0.24	±0.07
2007	25	1.84	±0.31	0.46	±0.08

Steelhead densities according to habitat type are represented in Figure 54. While coho juveniles strongly favor pool habitat, steelhead show less discrimination between habitat types, perhaps due in part to competition from coho for available pool habitat.

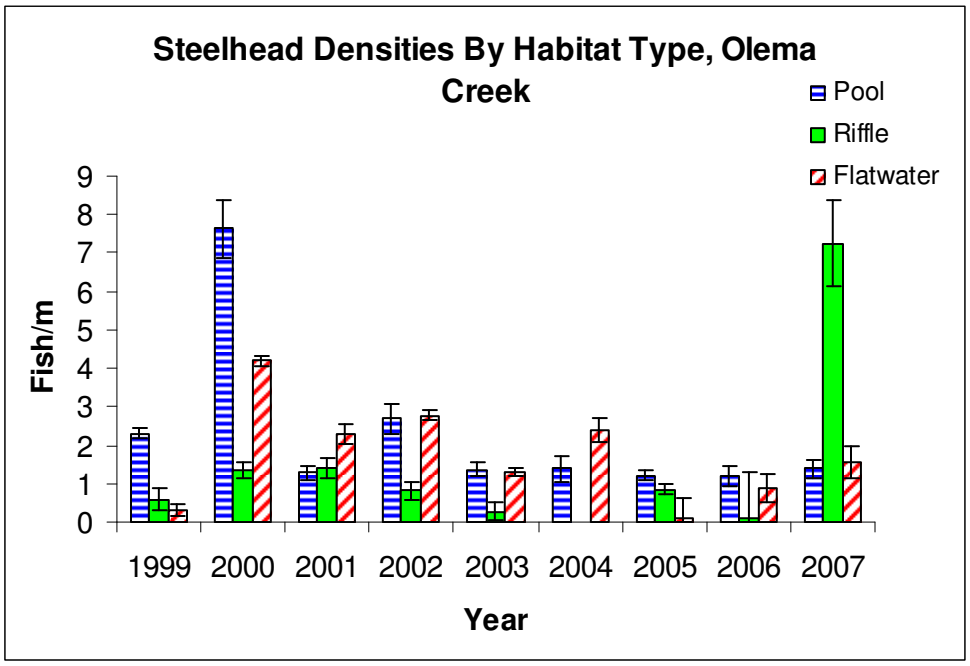


Figure 54. Steelhead densities by habitat type on Olema Creek, 1999-2007.

Densities used in Figure 55 were determined from all habitat units surveyed within each index reach in 2007. Coho densities are highest in index reaches 4, 5, and 7 while steelhead densities are highest in index reach 3.

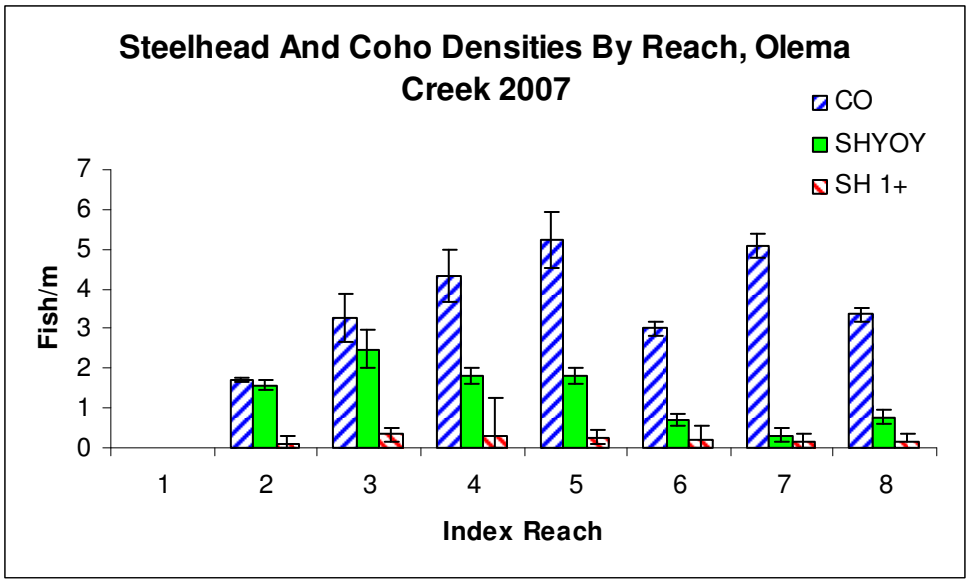


Figure 55. Coho and steelhead densities according to index reach on Olema Creek, 2007.

3.13.3 Juvenile Fish Weight-Length Relationships

As part of the summer monitoring program, a subsample of fish are weighed and measured within each sampled habitat unit. Histograms are presented for coho (Figure 56) and steelhead (Figure 58). Weight-length relationships are shown for coho (Figures 57) and steelhead (Figure 59). Fork lengths and weight-length relationships from previous years are also presented. Historic data prior to 2004 are not currently available due to an inconsistency in data collection techniques used prior to 2004.

Within the Olema Creek sample, 334 coho salmon (24% of the total index reach catch) and 322 steelhead trout (40% of the total index reach catch) were weighed and measured. The size range for coho was observed to be 41 to 120 mm, while the size range for steelhead trout was 31 to 215 mm. In previous years, the size range observed for coho was 46 to 121 mm, with a mean of 65.3 mm. For steelhead in previous years, the range was 34 to 270 millimeters, with a mean of 86.3 mm. We speculate that both coho and steelhead over 90 mm in size represent fish from the previous year class. A total of three coho were greater than 90 mm when measured. Summer 2004 was the first year that coho in excess of 99 mm have been observed as part of the Olema Creek summer monitoring efforts (Ketcham et. al. 2004).

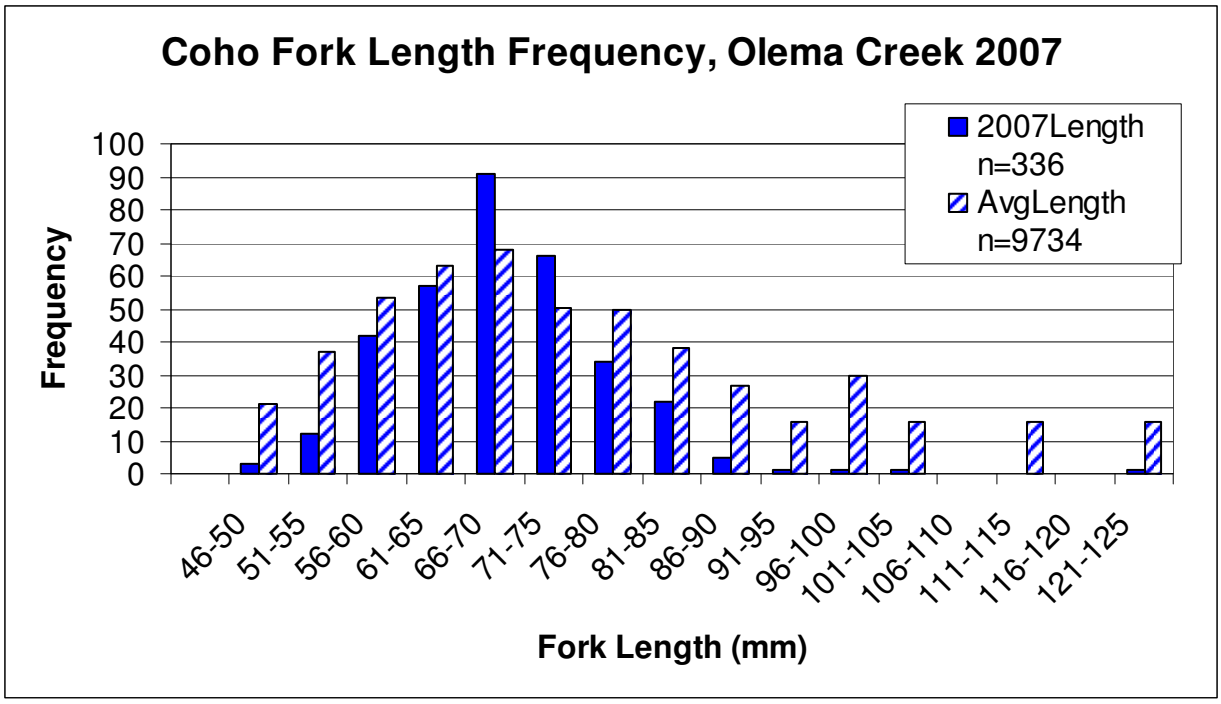


Figure 56. Coho histogram for fish measured in the seven Olema Creek index reaches, 2007. Average lengths (2004-2006) are shown for comparison. Fork length is represented in 5-millimeter bins.

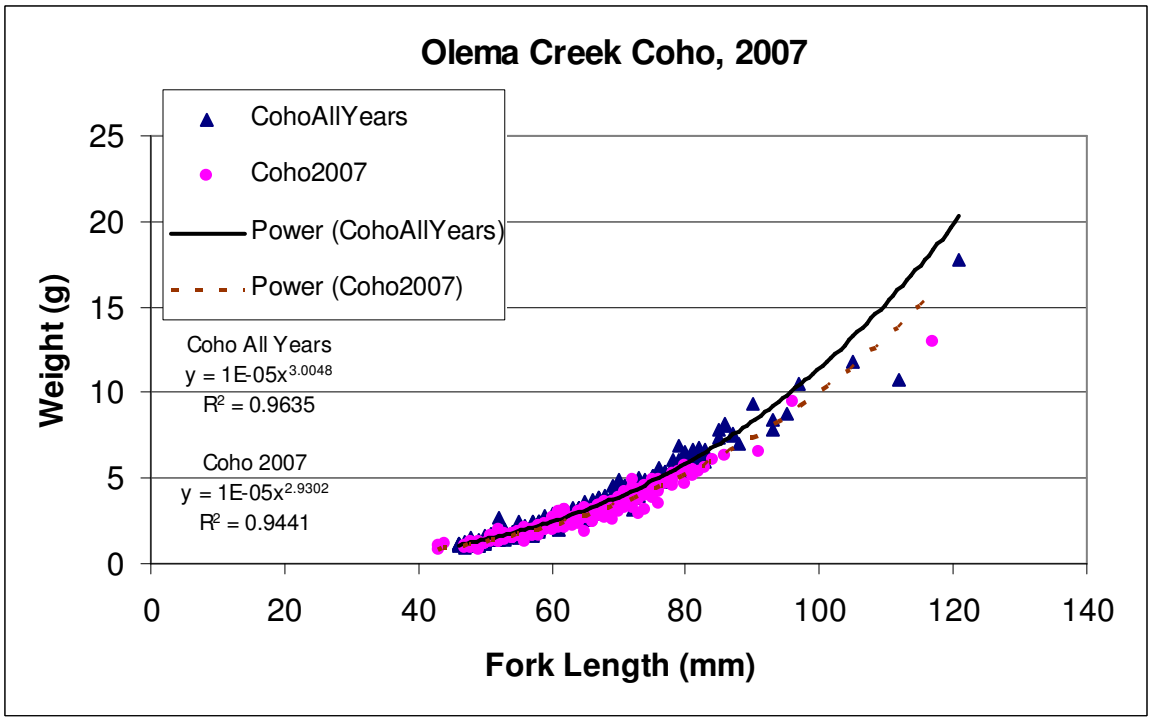


Figure 57. Coho weight-length relationships for fish measured in the seven Olema Creek index reaches, 2007. Weight-length relationship for coho from 2004-2006 shown for comparison.

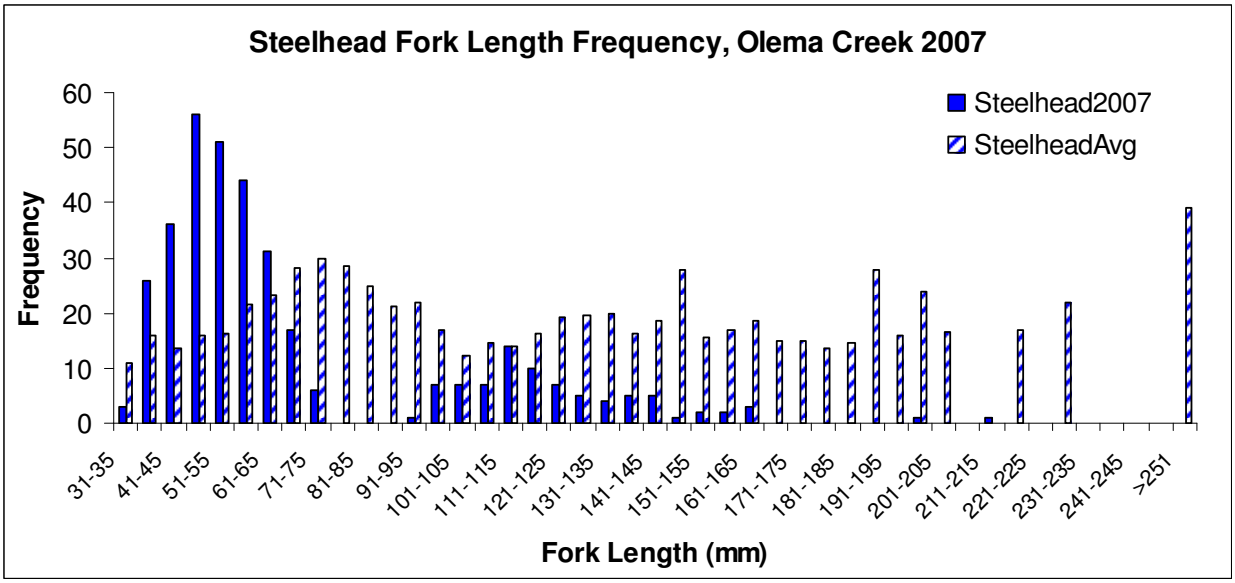


Figure 58. Steelhead histogram for fish measured in the seven Olema Creek index reaches, 2007. Fork length is represented in 5 millimeter bins. Multiple peaks represent multiple year classes of *O. mykiss*. Average fork length frequency for steelhead from years 2004-2006 provided for comparison.

The steelhead data points for 2007 fit a linear regression line, whereas the steelhead from previous years (2004-2006) fit a power regression line.

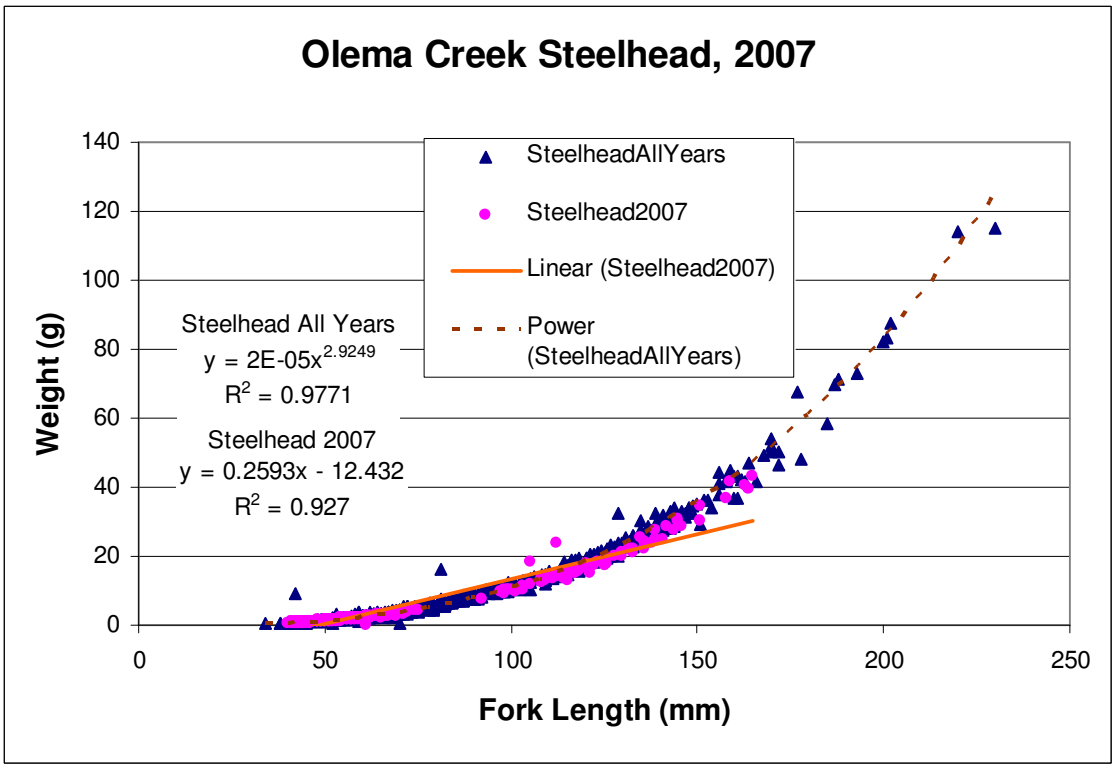


Figure 59. Steelhead weight-length relationships for fish measured in the seven Olema Creek index reaches, 2007. Weight-length relationships for steelhead 2004-2006 are shown for comparison.

Length is the principal factor affecting the weight of fishes. In spite of this, there can be significant differences in weight distribution between similar size fish of the same species within a particular watershed and within the surrounding region. In order to compare length-weight relationships, we applied the Fulton Condition Factors (K) to establish comparable indices of condition (Murphy and Willis 1996). Condition factors are a ratio relating fish length to fish weight therefore measuring the relative biomass of a fish. Table 40 shows the coho length, weight, and K-factor for Olema Creek. Tables 41 and 42 show the comparisons between steelhead young of the year (YOY) and steelhead 1+ length, weight, and K-factors for Olema Creek.

Table 40. Mean coho length, weight, K-factor, and standard deviation (SD) calculated for coho measured and weighed in the seven Olema Creek index reaches 2004-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2004	195	61.06	9.87	2.76	1.73	1.13	0.11
2005	287	56.13	3.38	2.05	0.35	1.15	0.10
2006	81	75.63	7.23	5.13	1.60	1.15	0.08
2007	334	63.98	8.80	2.85	1.26	1.04	0.10
Total	**897**	**65.43**	**8.94**	**3.38**	**1.58**	**1.11**	**0.10**

Table 41. Mean steelhead length, weight, K-factor, and standard deviation (SD) calculated for steelhead YOY measured and weighed in the seven Olema Creek index reaches 2004-2007.

Year	Sample Size	Mean Length (mm)	Length Standard Deviation	Mean Weight (g)	Weight Standard Deviation	Mean K-Factor	K-Factor Standard Deviation
2004	159	55.07	10.53	2.22	1.50	1.22	0.90
2005	239	68.59	10.14	3.90	1.90	1.13	0.12
2006	218	67.44	7.95	3.62	1.23	1.13	0.10
2007	241	54.08	7.82	1.74	0.78	1.04	0.12
Total	**857**	**61.99**	**11.72**	**2.96**	**1.77**	**1.12**	**0.40**

Table 42. Mean steelhead length, weight, K-factor, and standard deviation (SD) calculated for steelhead 1+ measured and weighed in the seven Olema Creek index reaches in 2004-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2004	81	127.31	24.03	23.54	14.10	1.05	0.09
2005	53	140.92	27.52	32.77	17.05	1.05	0.07
2006	137	108.55	25.88	16.53	12.19	1.14	0.19
2007	80	121.73	17.51	18.74	8.13	0.99	0.12
Total	**351**	**121.24**	**26.58**	**21.35**	**15.05**	**1.07**	**0.15**

3.14 Pine Gulch Creek Index Reach Monitoring Summary

Index reach monitoring was initiated at eight sites on Pine Gulch Creek in 2000. The stream kilometer (km) location of each index reach is presented in Table 43. For detailed results at each location, please refer to Del Real et al. 2008.

Table 43. Site location and number for Pine Gulch Creek index sites.

Index site	Name/Location	Location Stream km
1a	Marin County Open Space District (MCOSD)	0.2
1b	Murch	0.4
1c	Weber	0.7
2	Paradise Valley	2.7
3	Pine Gulch Gorge	3.9
4*	BCPUD pasture	5.1
5	Lower Texeira	6.8
6	Upper Texeira	7.8

*not sampled in 2007 due to access issues.

In 2007, seven of eight index reaches on the mainstem of Pine Gulch Creek were sampled. Index reach electrofishing surveys were conducted on Pine Gulch Creek from July 31 through August 16, 2007. No coho were present in any of the reaches sampled. This is the first time since the return of coho was documented in 2001, that no juveniles were observed through the index reach surveys. No coho were observed during the basinwide snorkel surveys.
Index Reach Habitat and Total Catch: The results presented in Table 44 are the real catch documented through electrofishing activities, as well as salmonid sample size variation between reaches, 2000-2007.

Table 44. Summary of total catch for each species by reach within Pine Gulch Creek mainstem index reach sample locations between 2000-2007.

Year	Species	Index Reach								Total
		1a	1b	1c	2	3	4	5	6	
2000	CO	0	0	0	0	0	0	0	0	0
	SH YOY	16	71	74	75	76	84	51	30	477
	SH 1+	3	16	28	21	14	21	19	6	128
2001	CO	0	1	0	4	15	0	31	0	51
	SH YOY	4	55	64	55	47	57	27	15	324
	SH 1+	1	11	22	46	20	15	32	23	170
2002	CO	0	1	2	11	16	34*	24	6	94
	SH YOY	11	73	51	110	244	-	90	86	665
	SH 1+	6	22	29	14	18	-	25	18	132
2003	CO	0	0	0	10	12	not	8	1	31
	SH YOY	24	87	72	115	185	sampled	64	20	567
	SH 1+	13	17	22	24	15		20	13	124
2004	CO	0	1	1	2	1	not	0	0	5
	SH YOY	10	80	55	99	144	sampled	80	46	514
	SH 1+	6	18	33	12	16		16	4	105
2005	CO	3	1	0	2	15	not	16	8	45
	SH YOY	25	18	44	78	41	sampled	40	33	279
	SH 1+	8	5	33	18	17		24	7	112
2006	CO	0	0	0	0	0	not	4	10	14
	SH YOY	9	22	17	17	45	sampled	39	20	169
	SH 1+	31	28	38	13	18		17	18	163
2007	CO	0	0	0	0	0	not	0	0	0
	SH YOY	3	39	61	145	153	sampled	55	52	508
	SH 1+	2	21	29	23	13		23	14	125

*snorkel survey result

3.14.1 Index Reach Habitat Information

In 2007, no coho were found within the index reaches, though steelhead were present in all index reaches. Other aquatic species sampled at each index reach are documented.

Pine Gulch Creek Index reaches 1a through 1c were established to represent the lower reaches of the watershed where the stream flows through organic agricultural cropland. The NPS and other agencies are working with these landowners to enhance operations to protect instream flow for the benefit of coho salmon and steelhead trout. Sampling in these private lands is done with the cooperation of the landowners.

Index Reach 1a: is located in the lowest 200 meters of freshwater habitat within Marin County Open Space District Land. One scour pool habitat unit was sampled in this reach, comprising 100% of the area sampled. In previous years, pool units have made up between 64 and 100% of the available habitat. In 2007, the upstream half of the index reach was obstructed by a large woody debris jam thus limiting the sampling area to the one pool. Also present in Index 1a were ammocetes, roach, sticklebacks and sculpins.

Index Reach 1b: is located just upstream of the NPS stream gage on the Murch property. Reach 1b consisted of four habitat units, including two pool units and two flatwater units. Pool units made up 44.3% of the total length. In previous years, pool units made up between 50 and 69% of available habitat. Also present in Index 1b were ammocetes, roach, sticklebacks and sculpins.

Index Reach 1c: is located 100 m upstream of the Olema-Bolinas Road Bridge on the Star Route Farms property. Reach 1c consisted of five habitat units, including three pool units and two riffles. Pool units made up 92% of the total length. In previous survey seasons, pool units made up between 77 and 89% of the available habitat. Also present in Index 1c were ammocetes, roach, sticklebacks, crayfish and sculpin.

Index Reach 2: is located near stream km 2.8. This reach is located in Paradise Valley on land recently purchased from the Martinelli Family Trust. The new landowner is supportive of ongoing monitoring activities. The riparian habitat is primarily hardwood including alder and bay trees. Reach 2 consisted of 5 habitat units, including two pool units, one flatwater unit and two riffle units. Pool units made up 56.5% of the total length. In previous years, pool units made up between 62 and 96% of the available habitat. Also present in Index 2 were ammocetes, sticklebacks and sculpins.

Index Reach 3: is located near stream km 3.9, at the lower end of the gorge. This is a steep canyon area with dense riparian cover, and deep stable bedrock controlled habitat. Reach 3 consisted of five habitat units, including two pool units, two riffle units and one flatwater unit. Pool units made up 53.3% of the total length. In previous years, pool units made up between 45 and 66% of available habitat. Also present in Index 3 were ammocetes, sticklebacks, salamanders, newts and sculpins.

Index Reach 4: Not sampled in 2007, nor the previous seven years.

Index Reach 5: is located near stream km 6.8 within the Texiera Flats area. A total of five habitat units were sampled, including three pool units, and two riffles. Pool units made up 69.7% of the total length. In previous years, pool habitat made up 55-59% of available habitat. Also present in Index 5 were ammocetes and sculpins.

Index Reach 6: is located near stream km 7.8 upstream of the Texiera House. Reach 6 contained a total of five habitat units, including three pool units and two riffle units. Pool units made up 61.3% of the total length. In previous years, pool habitat made up between 44 and 64% of available habitat. Also present in Index 6 were ammocetes, sculpins and a salamander.

Figure 60 shows a comparison of habitat composition between the index reaches, and between the 2007 surveys and the averages of previous years. Three of the seven surveyed index reaches had a higher than average percentage of pool habitat, ranging from 7.1% higher (Index 6) to 13.2% higher (Index 5). While Index 1a did have an increase of 17.8% in pool habitat, that increase may not reflect the real percentages, due to the restricted amount of Index 1a that was sampled as a result of the large woody debris jam on the upper portion of the reach.

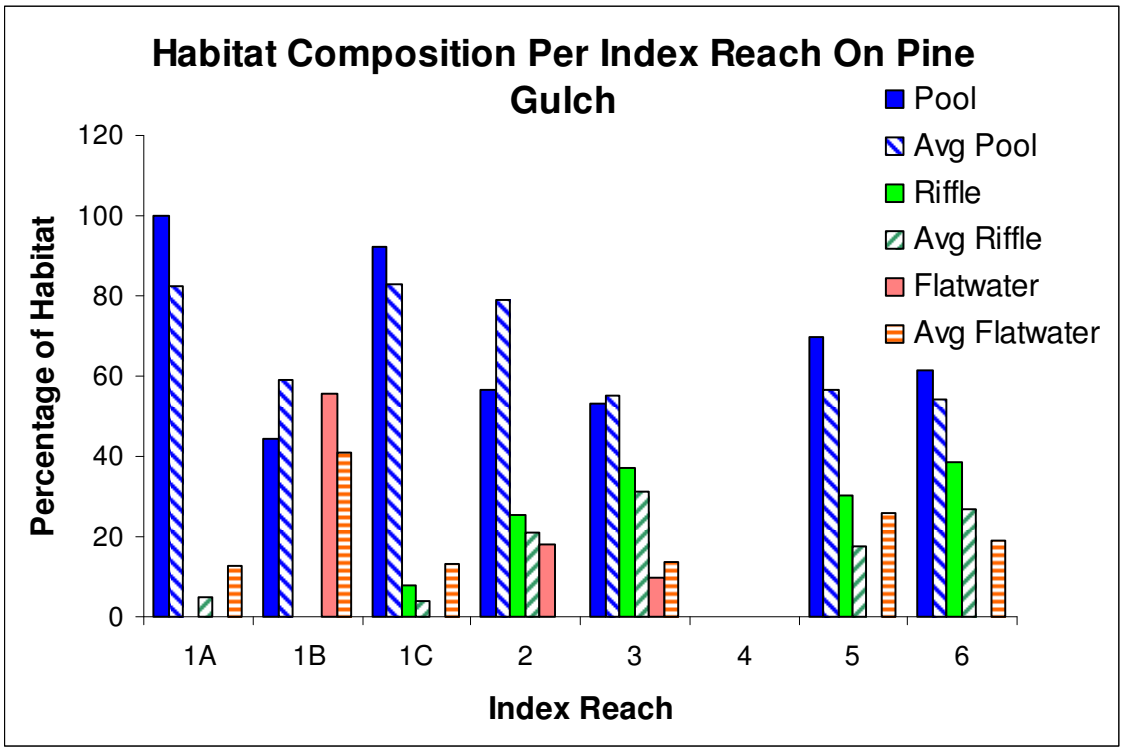


Figure 60. Habitat composition according to index reach on Pine Gulch Creek, 2007. Also shown are the cumulative average percentages of each unit type for survey years 2005-2006.

3.14.2 Salmonid Density by Habitat Type

Pools are typically the best habitat for both coho salmon and steelhead trout, and consistently support higher densities than flatwater and riffle units. As observed in Olema Creek, steelhead occur in all habitat types, though in varying densities. Without the presence of the coho, they favor pool habitats over riffles and flatwaters. Historic Pine Gulch coho numbers and densities

based on habitat type are not included in this report due to low annual catch totals and inadequate confidence intervals.

Table 45 shows the breakout of habitat units and fish densities for steelhead young of year. Densities have ranged from 0.59 fish per meter to 2.03 fish per meter. No coho were observed within the seven sampled Pine Gulch Creek index reaches in 2007.

Table 45. Summary of population and density estimates from electrofishing surveys for steelhead YOY by habitat unit Pine Gulch Creek 2000-2007.

Year	Habitat Type	Habitat Units	Population Estimate		Density			
			No. fish	95% CI	Fish/m	95% CI	Fish/m^2	95% CI
2000	Pool	19	433	±391	1.34	±1.21	0.38	±0.33
	Riffle	11	22	±55	0.20	±0.49	0.07	±0.17
	Flatwater	4	79	±25	1.04	±0.32	0.36	±0.11
2001	Pool	22	218**	±115	0.67	±0.35	0.22	±0.11
	Riffle	8	4**	±63	0.09	±1.34	0.06	±0.90
	Flatwater	4	45**	±23	0.54	±0.28	0.21	±0.11
2002	Pool	21	619	±238	2.03	±0.78	0.64	±0.25
	Riffle	9	41	±53	0.36	±0.47	0.19	±0.25
	Flatwater	4	55	±22	1.18	±0.46	0.46	±0.18
2003	Pool	16	447	±107	1.90	±0.46	0.63	±0.15
	Riffle	7	111	±46	1.31	±0.54	0.52	±0.21
	Flatwater	4	56	±19	0.84	±0.28	0.33	±0.11
2004	Pool	14	363	±46	1.77	±0.23	0.51	±0.06
	Riffle	7			*not surveyed			
	Flatwater	9	154	±36	1.22	±0.28	0.47	±0.11
2005	Pool	12	233	±39	0.93	±0.16	0.26	±0.04
	Riffle	6	18	±58	0.47	±1.51	0.18	±0.57
	Flatwater	6	33	±14	0.49	±0.20	0.18	±0.07
2006	Pool	15	147	±30	0.59	±0.12	0.18	±0.04
	Riffle	11	9	±95	0.10	±1.06	0.05	±0.51
	Flatwater	5	15	±32	0.28	±0.58	0.08	±0.17
2007	Pool	16	404	±58	1.60	±0.23	0.49	±0.07
	Riffle	10	79	±46	0.90	±0.53	0.32	±0.19
	Flatwater	4	44	±17	0.73	±0.22	0.22	±0.15

*Riffles were not surveyed in 2004 due to low flow conditions.
**Index 4 totals excluded from population estimate in order to compare year class estimates.

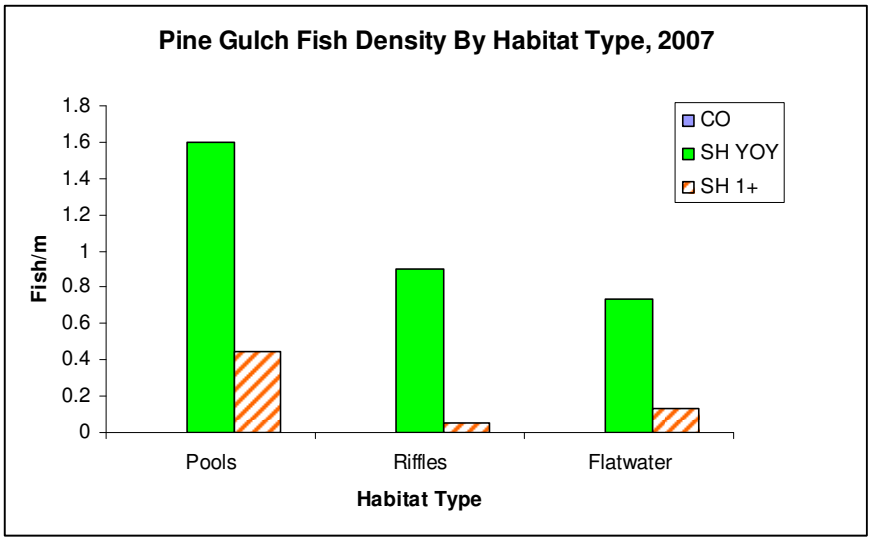


Figure 61. Fish densities according to habitat type, Pine Gulch Creek 2007.

Table 46. Summary of average density estimates from electrofishing surveys for steelhead YOY on Pine Gulch Creek 2000-2007.

Year	No. Habitat Units	Density			
		Fish/m	95% CI	Fish/m^2	95% CI
2000	34	1.05	±0.92	0.31	±0.27
2001	34	0.59	±0.44	0.21	±0.16
2002	34	1.54	±0.67	0.55	±0.24
2003	27	1.59	±0.44	0.56	±0.16
2004	30	1.56	±0.25	0.50	±0.08
2005	24	0.80	±0.31	0.24	±0.09
2006	31	0.43	±0.40	0.14	±0.13
2007	30	1.32	±0.30	0.42	±0.10

Densities used in Figure 62 are determined from all habitat units surveyed within each index reach. While there were no coho found in Pine Gulch in 2007, the highest steelhead densities were observed in index reaches 2 and 3. Historically, the highest densities for steelhead young of year have occurred in index reaches 2 through 4, while coho were found spread across all reaches, with higher densities generally found in the upper reaches.

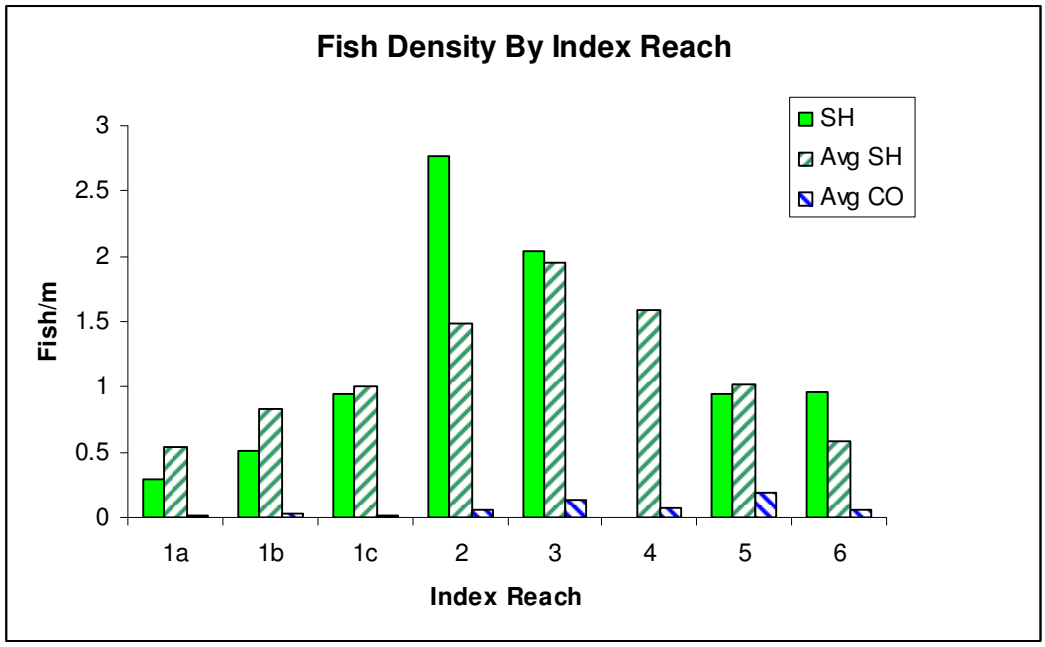


Figure 62. Fish density by index reach on Pine Gulch Creek, 2007. Historic (2000-2007) averages of steelhead YOY and coho juveniles are shown for comparison.

3.14.3 Juvenile Fish Weight-Length Relationships

As part of the summer monitoring program, a subsample of fish are weighed and measured within each sampled habitat unit. A fork length histogram is presented for steelhead (Figure 63). Weight-length relationships are shown for steelhead (Figure 64). Within the Pine Gulch Creek sample, 417 steelhead trout (66% of the total index reach catch) were weighed and measured. The size range for steelhead trout was 31 to 245 millimeters.

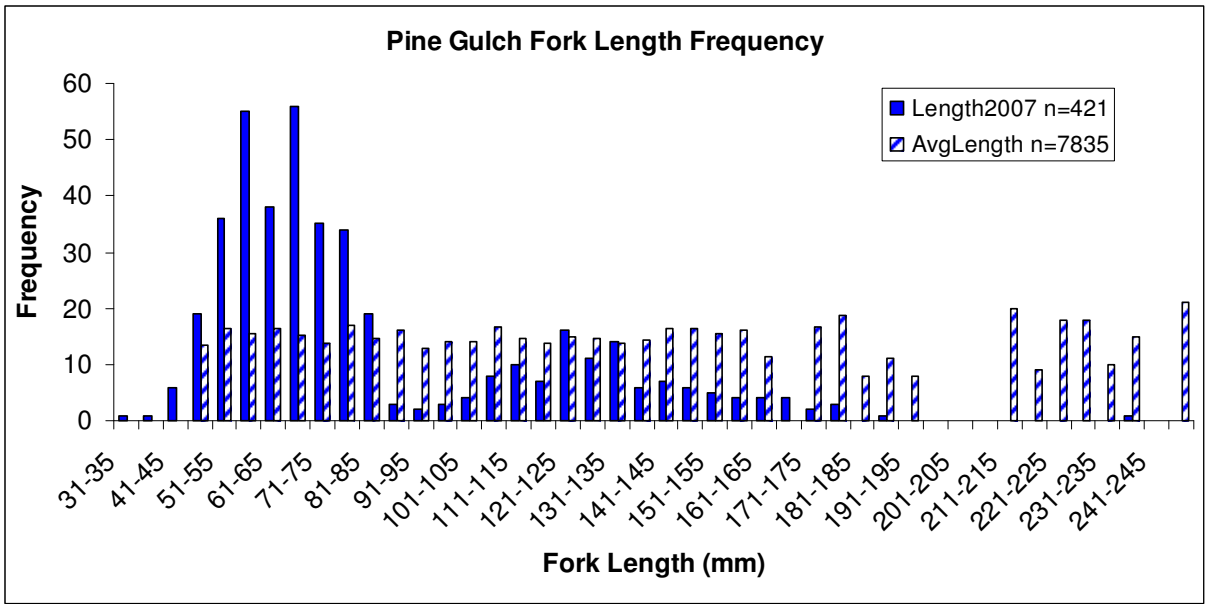


Figure 63. Steelhead histogram for fish measured in the seven Pine Gulch Creek index reaches, 2007. Shown for comparison are the historic averages taken during previous years (2005-2006). Fork length is represented in 5 millimeter bins. Multiple peaks represent multiple year classes of *O. Mykiss*.

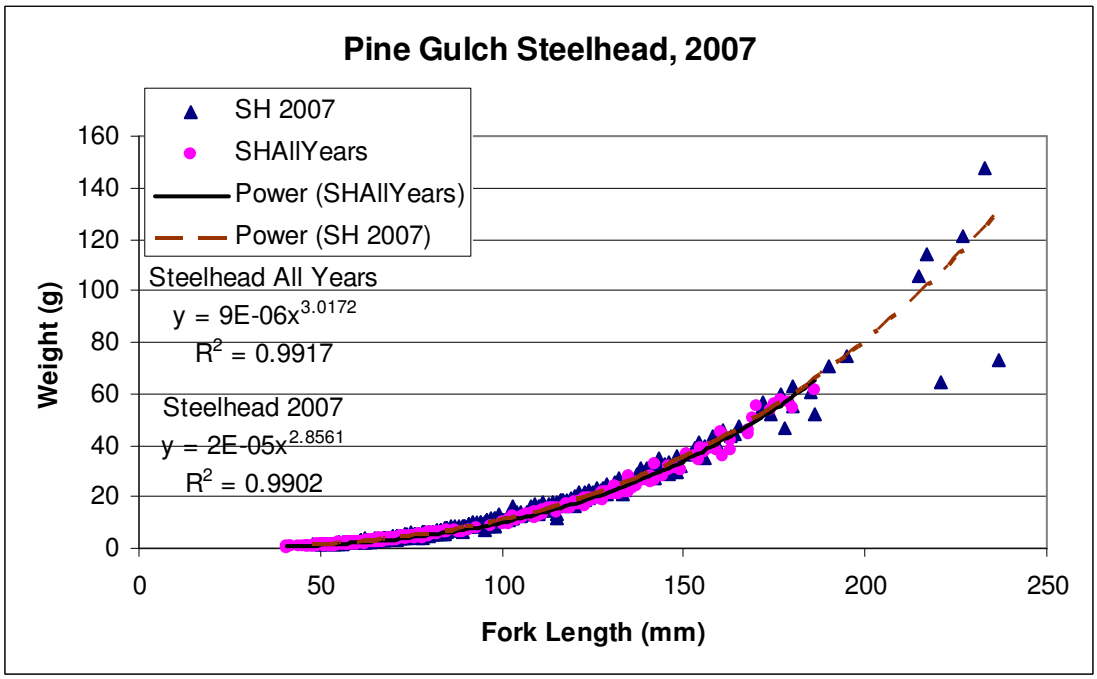


Figure 64. Steelhead weight-length relationships for fish measured in the seven Pine Gulch Creek index reaches, 2007. Shown for comparison are historic data taken from previous years (2005-2006).

Condition factors are a ratio relating fish length to fish weight therefore measuring the relative biomass of a fish. Tables 47 and 48 show the comparisons between steelhead young of the year (YOY) and steelhead 1+ length, weight, and K-factors for Pine Gulch Creek, taken from survey years 2005-2007.

Table 47. Mean length, weight, K-factor, and standard deviation (SD) calculated for steelhead YOY measured and weighed in the seven Pine Gulch Creek index reaches 2005-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2005	213	71.17	9.68	4.45	1.83	1.17	0.09
2006	157	78.72	8.84	5.84	1.91	1.56	0.10
2007	300	64.73	10.42	2.97	1.46	1.00	0.10
Total	**670**	**68.43**	**11.30**	**3.76**	**1.96**	**1.06**	**0.12**

Table 48. Mean length, weight, K-factor, and standard deviation (SD) calculated for steelhead 1+ measured and weighed in the seven Pine Gulch Creek index reaches 2005-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2005	106	130.52	27.44	27.29	22.45	1.08	0.08
2006	123	123.43	26.21	22.12	13.42	1.09	0.12
2007	300	64.73	10.42	2.97	1.46	1.00	0.10
Total	**429**	**129.36**	**24.2**	**24.45**	**15.52**	**1.04**	**0.10**

3.15 Redwood Creek Index Reach Monitoring Summary

Dr. Jerry Smith (SJSU) established five index reaches on Redwood Creek in 1992; monitoring of these sites were shared between Dr. Smith and NPS until 2004. Historical average salmonid density estimates from electrofishing surveys completed by Dr. Jerry Smith on Redwood Creek from 1992-2001 are located below in Table 50. Two additional index sites, Muir Woods National Monument (MUWO) boardwalk and Banducci, were added by Golden Gate National Recreation Area (GOGA) in 2001 to represent habitat units not being covered by Dr. Jerry Smith. Since 2004, all seven index reaches have been monitored by NPS staff. The stream kilometer (km) location of each index reach is presented in Table 49. In 2007, all seven index reaches on the mainstem of Redwood Creek were sampled. For detailed results at each location, please refer to Del Real et al. 2008.

Table 49. Site location and number for Redwood Creek index reach sites.

Index site	Name/Location	Location stream km
1	MUWO boardwalk	6.3
2	MUWO restroom	5.2
3	Miwok Trail Crossing	3.8
4	Kent Creek	2.9
5	Frank Valley Road Bridge	1.9
6	Banducci	0.8
7	Pacific Way Bridge	0.1

Table 50. Summary of historical average salmonid density estimates from electrofishing surveys completed by Dr. Jerry Smith on Redwood Creek, 1992-2003.

Year	No. sampled indexes	Length sampled (m)	Density CO/m	Density SH YOY/m	Density SH 1+/m
1992	4*	314.6	1.48	0.75	0.13
1993	4	289.9	1.51	1.84	0.13
1994	7	392.3	0.07	2.26	0.46
1995	4	242.6	1.38	3.18	0.13
1996	3	184.1	1.28	1.08	0.36
1997	5*	299.9	0.75	0.49	0.16
1998	5	357.8	1.05	1.54	0.13
2000	6	328.3	0.04	1.28	0.49
2001	5*	291.4	0.89	0.20	0.20
2002	4	239.9	1.87	0.36	0.10
2003	4	213.7	0.89	0.98	0.26

*One or both of the sites downstream of the well were intermittent or dry.

3.15.1 Index Reach Habitat and Total Catch

The results presented in Table 51 are the real catch documented through electrofishing activities in the Redwood Creek index reaches between the years 2004 and 2007, as well as salmonid sample size variation between reaches.

Table 51. Summary of total catch (not including Dr. Jerry Smith information) for each species by reach within Redwood Creek mainstem index reach sample locations 2004-2007.

Year	Species	Index Reach 1	2	3	4	5	6	7	Total
2004	CO	not	42	95	74	159	71	not	441
	SH YOY	sampled	6	22	19	24	4	sampled	75
	SH 1+		19	8	17	15	13		72
2005	CO	23	59	77	93	164	236	338	990
	SH YOY	44	38	41	70	77	178	81	529
	SH 1+	5	12	12	10	14	9	4	66
2006	CO	6	21	21	38	3	9	0	98
	SH YOY	38	78	26	20	5	17	4	188
	SH 1+	2	24	21	20	11	20	1	99
2007	CO	54	138	215	120	146	89	8	770
	SH YOY	90	161	305	170	212	392	144	1,474
	SH 1+	8	43	10	11	7	11	7	97

In 2007, all index reaches included the presence of coho and steelhead. Other aquatic species sampled at each index reach are documented.

Index Reach 1: is located within Muir Woods (MUWO). Reach 1 consisted of eight habitat units, including three pool units, two flatwater units and three riffle units. Pool units made up 36.2% of the total length. In previous years, pool units comprised between 30.8 and 48.4% of available habitat. Also present in Index 1 were sculpins.

Index Reach 2: is located behind the MUWO restrooms. Reach 2 consisted of seven habitat units, including three pool units, two flatwater units and two riffle units. Pool units made up 40%

of the total length. Previous years, pool units made up between 37.2 and 80.7% of available habitat. Also present in Index 2 were sculpins, crayfish and salamanders.

Index Reach 3: is located near stream km 3.8 at the Miwok Trail footbridge crossing. Reach 3 consisted of six habitat units, including four pool units and two riffle units. Pool units made up 79.4% of the total length. In previous years, pools units comprised between 82.5 and 93.3% of available habitat units.Also present in Index 3 were sculpins, a salamander and crayfish.

Index Reach 4: is located near stream km 2.9 at the Kent Creek confluence on Redwood Creek. Reach 4 consisted of eight habitat units, including four pool units, two flatwater units and two riffle units. Pool units made up 69.9% of the total length. In previous years, pool units made up between 69.8 and 85.8% of available habitat. Also present in Index 4 were sculpins and crayfish.

Index Reach 5: is located near stream km 1.9 upstream of the Frank Valley Road bridge. Reach 5 consisted of five habitat units, including three pool units, one flatwater unit and one riffle unit. Pool units made up 68.9% of the total length. In previous years, pool units comprised between 54.2 and 95.8% of available habitat. Also present in Index 5 were sculpins and crayfish.

Index Reach 6: is located near stream km 0.8 at the Banducci restoration site. Reach 6 contained a total of four habitat units, including three pool units and a riffle unit. Pool units made up 92.1% of the total length. In previous years, pool units made up between 30.4 and 100% of avaible habitat. Also present in Index 6 were sculpins and crayfish.

Index Reach 7: is located near the Pacific Way Bridge, at stream km 0.1. Reach 7 contained a total of seven habitat units, including two pool units, three flatwater units and two riffle units. Pool units made up 41% of the total length. In previous years, pool units made up between 54.3 and 100% of available habitat. Also present in Index 7 were sticklebacks, sculpins and crayfish.

Figure 65 shows a comparison of habitat composition between the index reaches, and between the 2007 surveys and the historic averages for each reach. Only one of the seven surveyed index reaches had a higher than average percentage of pool habitat; the percentage of pool units in Index 6 was 10% higher than the historic average for that reach. The remaining six index reaches had a lower than average percentage of pool habitat, ranging from 2.6% to 36.2% lower than the historic averages.

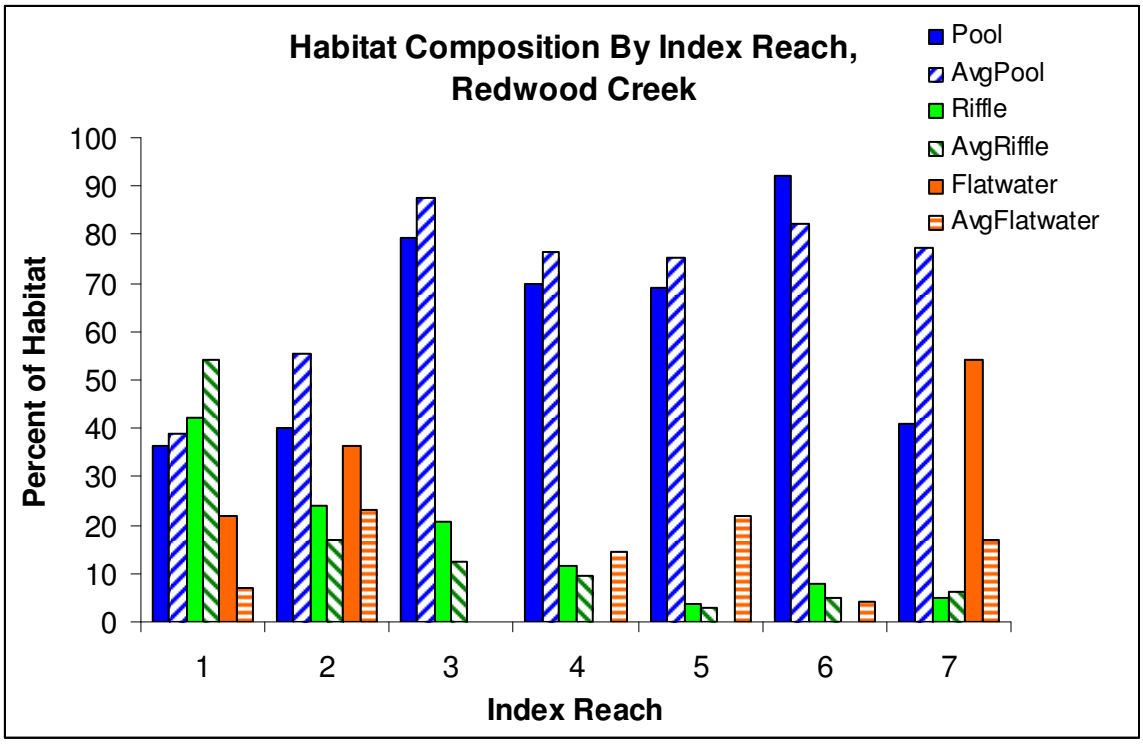


Figure 65. Habitat composition by index reach 2007. averages are put in for comparison.

3.15.2 Salmonid Density by Habitat Type

The results of our monitoring efforts show distinct differences in salmonid numbers and densities based on habitat type (Table 52). The results show distinct use of pools by coho with fish densities of 1.98 (±0.13) fish/meter and 0.52 (±0.03) fish/meter^2 occurring in this habitat.

Table 52. Summary of population and density estimates from electrofishing surveys for coho salmon by habitat unit on Redwood Creek, 2004-2007.

Year	Habitat type	No. Habitat Units	Population Estimate No. fish	95% CI	Density Fish/m	95% CI	Fish/m^2	95% CI
2004	Pool	13	428	±38	1.81	±0.16	0.46	±0.04
	Riffle				*Not Surveyed			
	Flatwater	4	23	±5	0.40	±0.08	0.16	±0.03
2005	Pool	19	977	±362	2.02	±0.75	0.48	±0.18
	Riffle	5	22	±80	0.24	±0.88	0.12	±0.44
	Flatwater	3	12	±27	0.24	±0.55	0.11	±0.25
2006	Pool	22	103	±149	0.25	±0.37	0.07	0.10
	Riffle	13	0	N/A	0	N/A	0	N/A
	Flatwater	6	0	N/A	0	N/A	0	N/A
2007	Pool	16	761	±51	1.98	±0.13	0.52	0.03
	Riffle	6	2	±109	0.02	±0.98	0.01	0.39
	Flatwater	3	12	±69	0.08	±0.46	0.03	0.16

* Riffles were not surveyed in 2004 due to low flow conditions.

Table 53. Summary of average density estimates from electrofishing surveys for coho salmon on Redwood Creek, 2000-2007.

Year	Total No. Habitat Units	Density			
		Fish/m	95% CI	Fish/m^2	95% CI
2004	17	1.53	±0.14	0.42	±0.04
2005	27	1.62	±0.75	0.43	±0.20
2006	41	0.17	±0.51	0.05	±0.14
2007	25	1.20	±0.36	0.35	±0.10

Figure 66 is a visual representation of coho juvenile density based on habitat type on Redwood Creek during summer surveys in 2004-2007. Coho juveniles show a marked preference for pool habitat, only rarely occurring in either riffle or flatwater habitat units within the survey reaches.

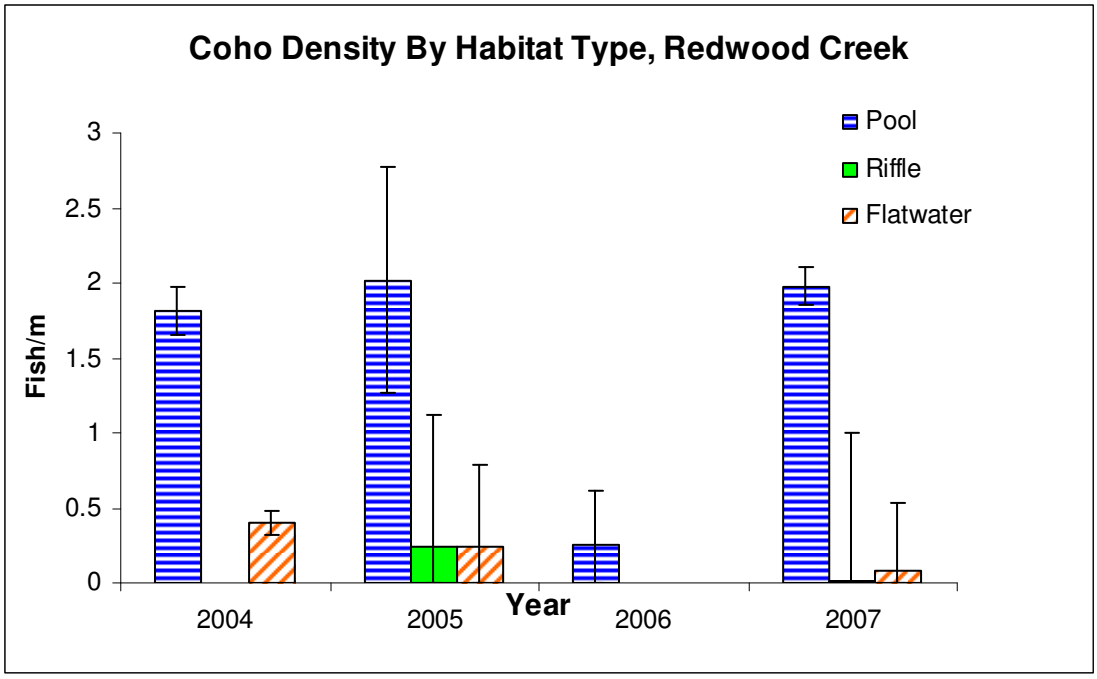


Figure 66. Comparison of coho density according to habitat type on Redwood Creek, 2004-2007.

Historically, steelhead young-of-year choose pool habitat over flatwater or riffle habitat, and in 2007, steelhead young-of-year again showed a strong preference for pool habitats with densities of 3.13 (±0.25) fish/meter. Flatwaters were a secondary choice, with densities of 1.71 (±0.43) fish/meter.

Table 54. Summary of population and density estimates from electrofishing surveys for steelhead YOY by habitat unit on Redwood Creek, 2004-2007.

Year	Habitat Type	No. Habitat Units	Population Estimate		Density			
			No. fish	95% CI	Fish/m	95% CI	Fish/m^2	95% CI
2004	Pool	13	61	±45	0.26	±0.19	0.07	±0.05
	Riffle				*Not Surveyed			
	Flatwater	4	16	±19	0.28	±0.32	0.11	±0.13
2005	Pool	19	479	±168	0.99	±0.35	0.23	±0.08
	Riffle	5	27	±40	0.30	±0.44	0.15	±0.22
	Flatwater	3	37	±10	0.75	±0.21	0.33	±0.09
2006	Pool	22	151	±80	0.37	±0.20	0.10	±0.05
	Riffle	13	18	±77	0.15	±0.64	0.05	±0.22
	Flatwater	6	19	±37	0.22	±0.44	0.07	±0.13
2007	Pool	16	1,200	±95	3.13	±0.25	0.82	±0.06
	Riffle	6	58	±60	0.52	±0.54	0.21	±0.22
	Flatwater	3	255	±65	1.71	±0.43	0.58	±0.15

*Riffles were not surveyed in 2004 due to low flow conditions.

Table 55. Summary of average density estimates from electrofishing surveys for steelhead YOY on Redwood Creek, 2000-2007.

Year	No. Habitat Units	Density			
		Fish/m	95% CI	Fish/m^2	95% CI
2004	17	0.26	±0.22	0.07	±0.06
2005	27	0.87	±0.35	0.23	±0.09
2006	41	0.31	±0.32	0.09	±0.09
2007	25	2.35	±0.34	0.69	±0.10

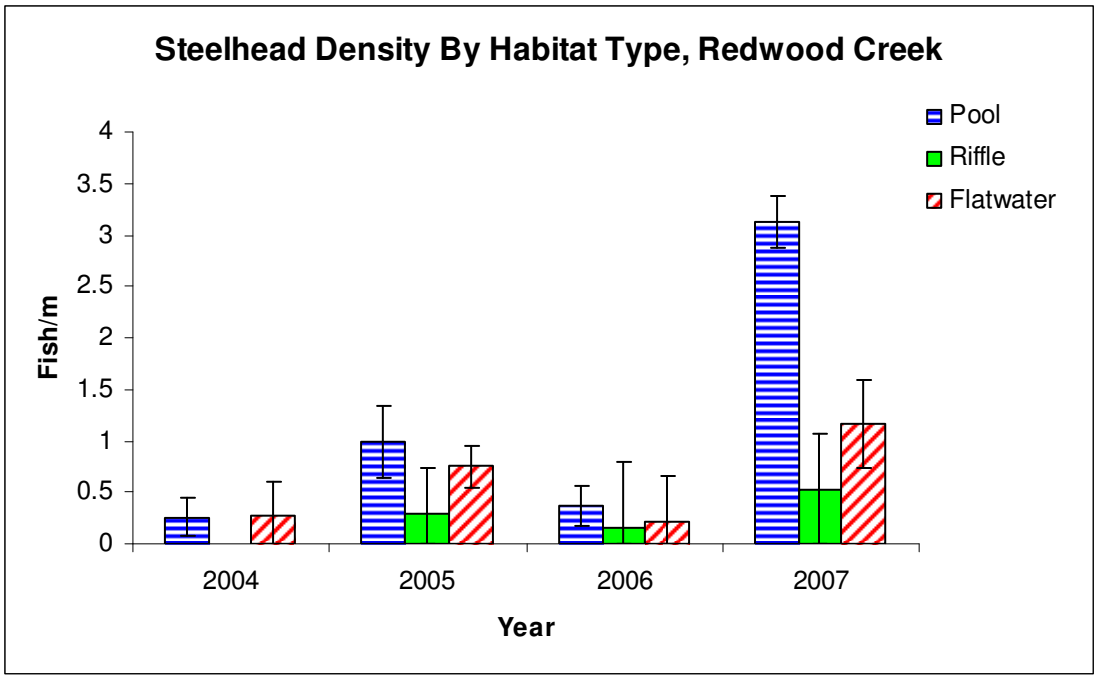


Figure 67. Steelhead YOY densities based on habitat type for Redwood Creek, 2004-2007.

Figure 67 is a visual representation of steelhead young-of-year densities based on habitat type between the years 2004 and 2007. As with coho, steelhead young-of-year prefer pool habitat. However, they show less discrimination than coho, and thus occupy a wider variety of habitats than do the coho.

Densities used in Figure 68 are determined from all habitat units surveyed within each index reach. Coho densities are highest in index reaches 3 and 4, while steelhead young-of-year densities are highest in index reaches 3 and 6. It should also be noted that steelhead young-of-year had a higher density than coho in every index reach surveyed.

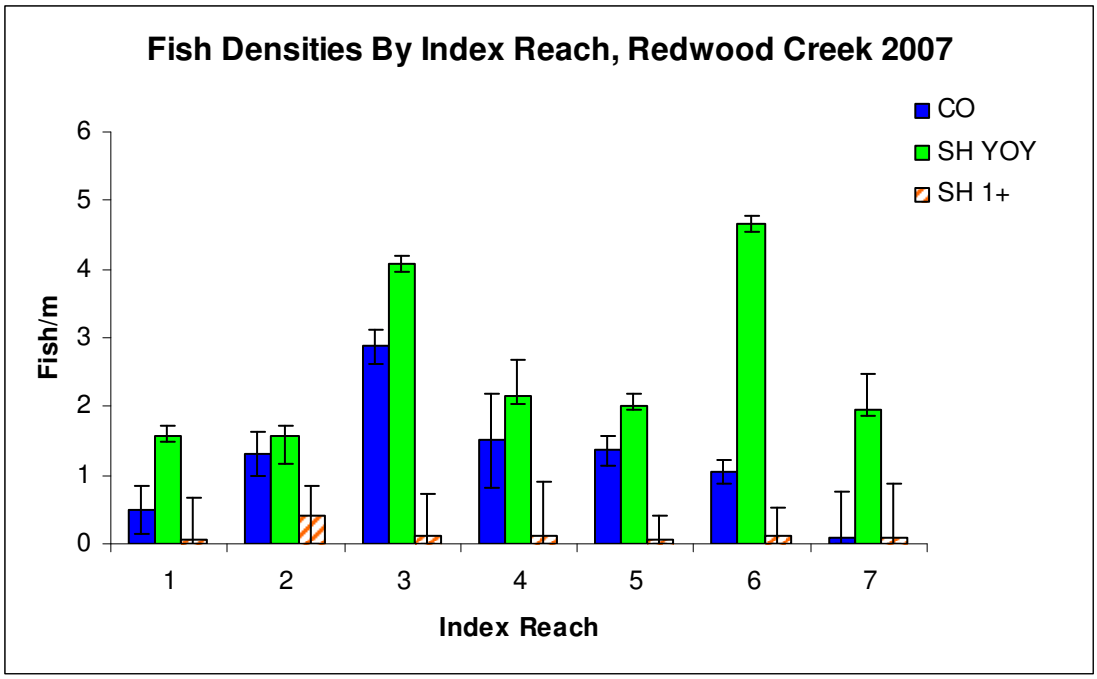


Figure 68. Fish densities by index reach for steelhead YOY, steelhead 1+, and coho during survey season 2007 on Redwood Creek.

3.15.3 Juvenile Fish Weight-Length Relationships

As part of the summer monitoring program, a subsample of fish are weighed and measured within each sampled habitat unit. Histograms are presented for coho (Figure 69) and steelhead (Figure 71). Weight-length relationships are shown for coho (Figures 70) and steelhead (Figure 72).

Within the Redwood Creek sample, 294 coho salmon (38% of the total index reach catch) and 626 steelhead trout (42% of the total index reach catch) were weighed and measured. The size range for juvenile coho was observed to be 51 to 110 mm, while the size range for steelhead trout was 36 to 200 mm.

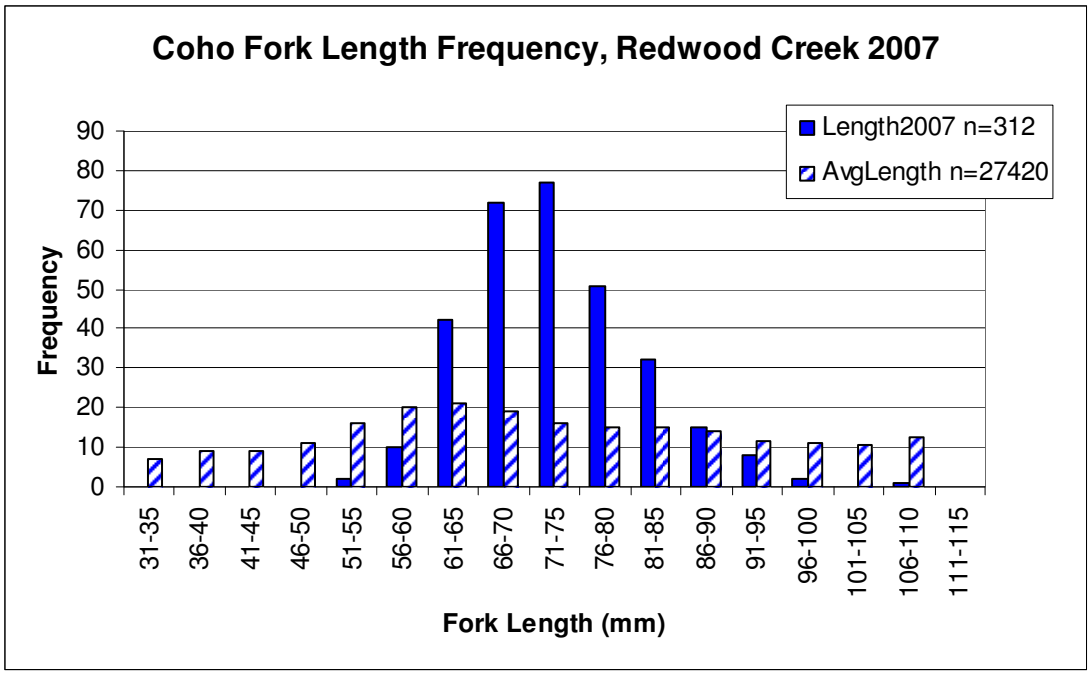


Figure 69. Coho histogram for fish measured in the seven Redwood Creek index reaches, 2007. Historical averages (1998-2006) are shown for comparison. Fork length is represented in 5 millimeter bins.

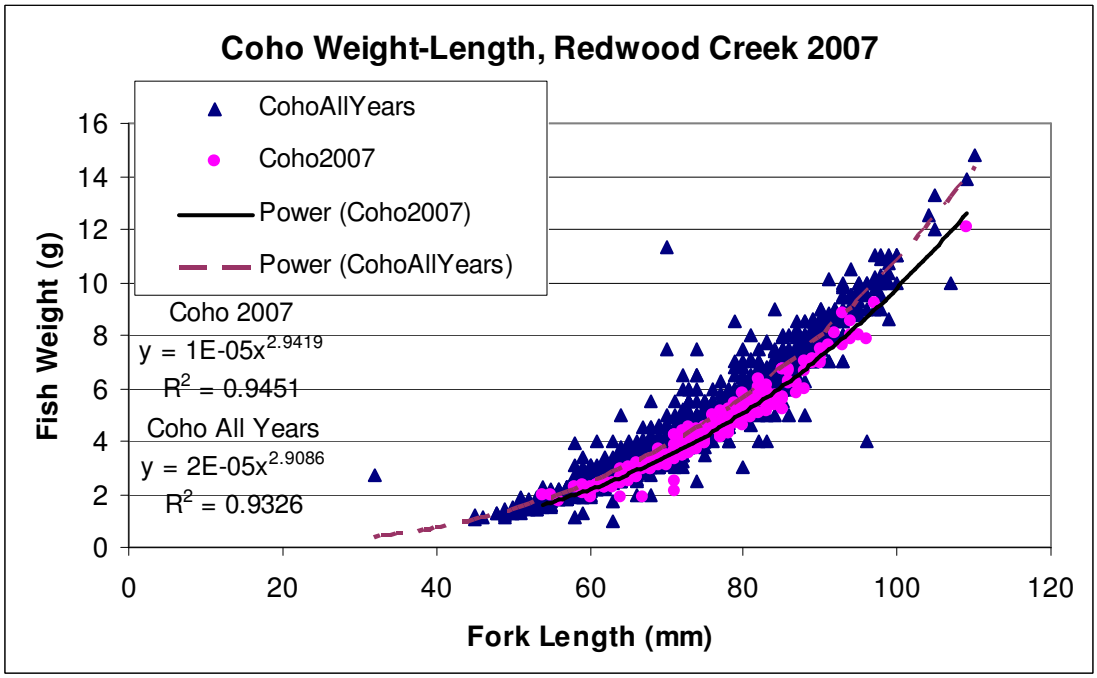


Figure 70. Coho weight-length relationships for fish measured in the seven Redwood Creek index reaches, 2007. Historical relationships added for comparison (1998-2006).

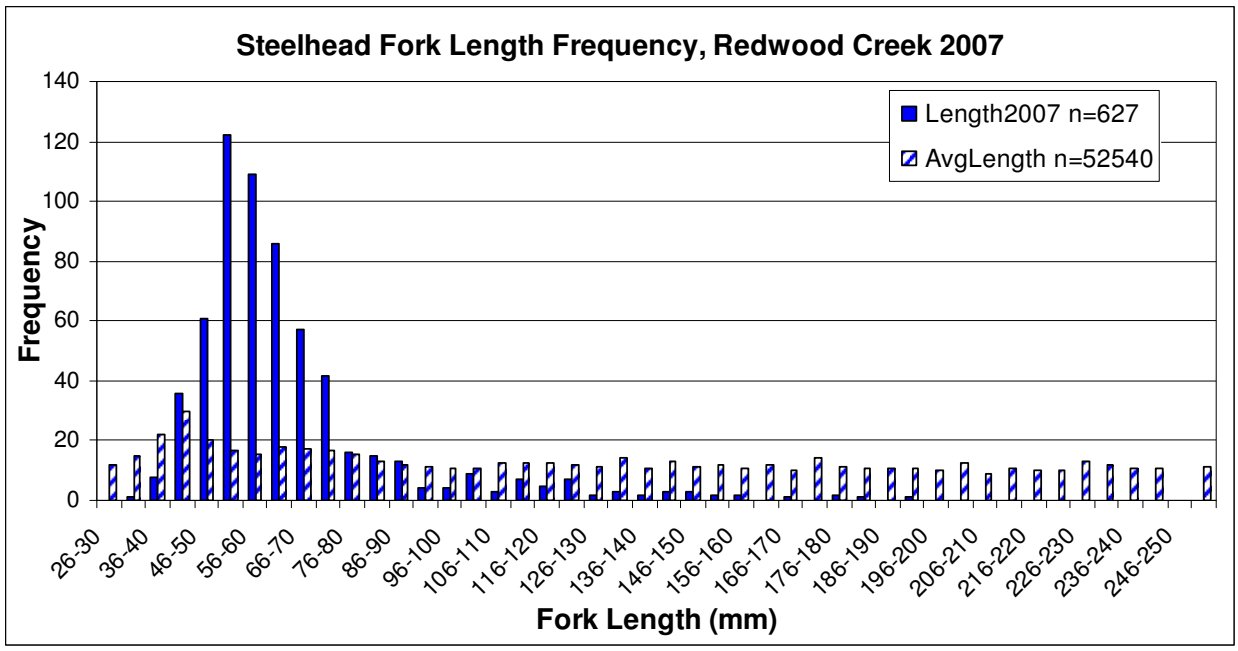


Figure 71. Steelhead histogram for fish measured in the seven Redwood Creek index reaches, 2007. Average historical frequency is added for comparison (1998-2006). Fork length is represented in 5 millimeter bins. Multiple peaks represent multiple year classes of steelhead trout.

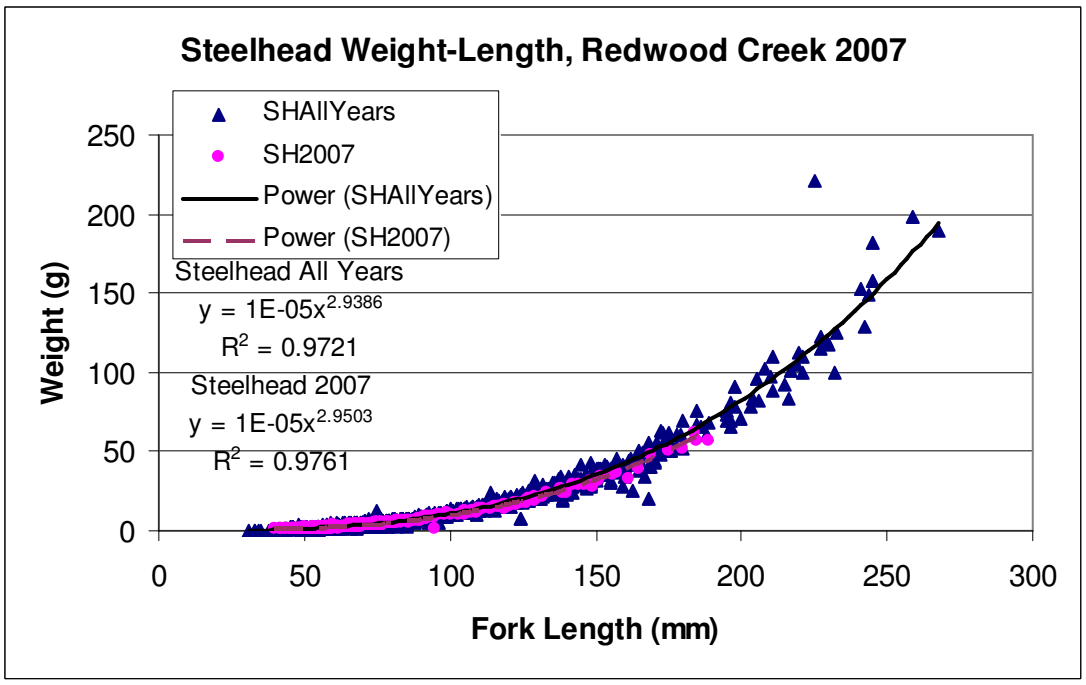


Figure 72. Steelhead weight-length relationships for fish measured in the seven Redwood Creek index reaches. Sample year 2007 is compared to all previous sample years (1998-2006).

Table 56 shows the coho length, weight, and K-factor for Redwood Creek between 1998 and 2007. Tables 56 and 57 show the comparisons between steelhead young of the year (YOY) and steelhead 1+ length, weight, and K-factors for Redwood Creek between 1998 and 2007.

Table 56. Mean length, weight, K-factor, and standard deviation (SD) calculated for coho measured and weighed in the seven Redwood Creek index reaches, 1998-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
1998	385	79.61	8.85	5.82	1.89	1.13	0.19
1999	256	74.70	9.28	5.11	2.85	1.18	0.63
2000	27	76.33	10.45	5.30	2.33	1.14	0.06
2001	234	66.00	8.24	3.45	1.32	1.18	0.50
2002	319	64.16	8.77	3.07	1.38	1.10	0.09
2003	92	76.61	9.94	5.19	2.10	1.10	0.07
2004	266	67.73	9.18	3.64	1.51	1.12	0.10
2005	333	72.17	8.07	4.39	1.59	1.13	0.07
2006	77	78.49	7.35	5.55	1.66	1.12	0.10
2007	294	73.73	8.38	4.15	1.49	1.00	0.08
Total	**2,283**	**72.13**	**10.20**	**3.49**	**2.04**	**1.10**	**0.18**

Table 57. Mean length, weight, K-factor, and standard deviation (SD) calculated for steelhead YOY measured and weighed in the seven Redwood Creek index reaches, 1998-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
1998	1241	69.47	11.02	3.98	2.02	1.12	0.25
1999	2,667	60.16	9.79	2.64	1.46	1.10	0.14
2000	210	66.67	9.90	3.68	1.67	1.17	0.19
2001	132	55.69	7.27	2.06	0.88	1.13	0.16
2002	195	57.41	8.03	2.26	0.97	1.14	0.12
2003	99	65.58	12.46	3.50	2.11	1.12	0.12
2004	100	68.08	13.76	3.87	2.26	1.11	0.12
2005	349	73.59	10.43	4.84	2.54	1.12	0.07
2006	161	78.98	10.43	5.67	2.30	1.10	0.11
2007	548	63.56	9.66	2.76	1.31	1.00	0.11
Total	**5,702**	**66.08**	**12.02**	**3.49**	**2.04**	**1.10**	**0.18**

Table 58. Mean length, weight, K-factor, and standard deviation (SD) calculated for steelhead 1+ measured and weighed in the seven Redwood Creek index reaches, 1998-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
1998	141	147.85	28.38	36.72	29.68	1.02	0.17
1999	189	124.41	22.81	23.35	21.19	1.08	0.08
2000	37	122.95	34.58	25.84	34.87	1.09	0.07
2001	101	103.84	22.62	13.54	12.10	1.06	0.08
2002	39	128.41	36.31	27.65	25.47	1.07	0.07
2003	41	132.32	36.18	29.09	25.83	1.05	0.09
2004	71	128.41	24.15	23.89	15.48	1.03	0.07
2005	51	141.36	26.29	33.23	21.61	1.07	0.06
2006	83	132.36	26.04	27.35	21.44	1.06	0.09
2007	78	122.15	26.21	19.54	13.13	0.95	0.11
Total	**831**	**129.13**	**29.31**	**26.10**	**23.35**	**1.05**	**0.10**

3.16 Olema Creek Juvenile Coho Salmon Basinwide Survey Summary

The 2007 summer habitat survey of Olema Creek was initiated at monument tag 25, downstream of the Olema Ranch Campground, and continued upstream to monument tag 150, adjacent to the Randall Ranch House. The measured basinwide survey length for the main channel was 12.7 km.

Basinwide snorkel surveys were conducted on 11.8 km of the Olema Creek mainstem starting at the Vedanta Retreat bridge and ending at the confluence with Randall Gulch.

3.16.1 Habitat Survey

A total of 930 mainstem habitat units were identified in the 12.7 km Olema Creek survey area. Pool units were the dominant habitat type measuring a total of 8.2 km. Overall habitat composition was 44% pool, 33% riffle, and 23% flatwater (Table 59). Intermittent conditions were observed approximately 11.9 km upstream from the mouth of Olema Creek. Dry sections of streambed accounted for 371 meters of the total length surveyed. Side channel and backwater units were also measured but not incorporated into the basinwide habitat analysis. Flatwater and riffle habitat types made up 81% of the total side channel habitat composition. Overall, 675 meters of side channel habitat and 324 meters of backwater habitat units were measured during the basinwide habitat survey.

Table 59. Habitat composition of Olema Creek coho survey area, 2003-2006 average and 2007.

Unit type	Average 2003-2006		2007	
	Length of Units (m)	%	Length of Units (m)	%
Pool	7,159	58	8,217	65
Flatwater	3,078	25	2,184	17
Riffle	2,164	17	2,297	18
Total	12,401		12,698	

Our observations indicate that side channel and backwater habitat (Table 60) may influence the success of emergent fry, especially during higher spring flow events. Our monitoring has been able to correlate a relationship between % side channel and backwater habitat, and observed egg to juvenile survival rates.

Table 60. Summer off-channel habitat densities of the Olema Creek mainstem, 2004-2007.

Unit type	2004		2005		2006		2007	
	Length (m)	Density (m per 100m)	Length (m)	Density (m per 100m)	Length (m)	Density (m per 100m)	Length (m)	Density (m per 100m)
Side Channel	261**	1.89	896.4	6.45	951.9	7.68	675.3	5.32
Backwater	144.4	1.05	117.8	0.85	322.9	2.60	324	2.55
Survey length*	13.8 km		13.9 km		12.4 km		12.7 km	

*Survey lengths are based on established monument tags for comparison between years.
**Summer 2004 had low base flow conditions with increased intermittent habitat.

In addition to habitat, woody debris information is collected during the basinwide habitat survey is summarized for 2005-2007 (Table 61) and may be used to identify trends in woody debris availability and recruitment trends over time. Within Olema Creek, the density of root wads and SWD jams has increased over the past three years, while all other metric densities are generally stable or reduced.

3.16.2 Snorkel Counts

In 2007, total of 917 habitat units were delineated within the 11.8 km Olema Creek snorkel survey area, with pool units representing 40% of all surveyed units. Snorkel surveys were conducted on 24% of the delineated pools with coho being observed in 97% of the sampled pools. A total of 6,688 coho were counted in the 89 snorkeled pools, giving a raw average of 75.15 coho per pool. Historically, coho have been observed in between 69% to 100% of the pool snorkeled.

Table 61. Summary of basinwide instream woody debris per 100 meters of Olema Creek mainstem during summer baseflow conditions including rootwads, large woody debris (LWD) jams, small woody debris (SWD) jams, and woody debris (WD) in 10-20 cm, 20-50 cm and greater than 50 dcm catagories.

Field season	Survey Length (# 100 m sections)	Rootwads Density per 100 m	LWD jams Density per 100 m	SWD jams Density per 100 m	10-20cm WD Density per 100 m	20-50cm WD Density per 100 m	>50cm WD Density per 100 m
2005	148.9	0.7	0.6	0.8	3.5	2.4	0.8
2006	142.3	1.0	0.5	0.6	2.4	2.2	1.0
2007	140.7	1.1	0.5	0.9	1.6	2.0	0.7

Sixteen of the 89 snorkeled pools (18.0%) were electrofished within a day following the snorkel counts. In addition to the 16 electrofished pools, seven pools were resnorkeled immediately following the initial pass using the method of bounded counts for calibration. *Microfish* and bounded count population estimates for the calibration pools were used to calibrate the snorkel counts. A summary of the snorkel counts for Olema Creek between 2003 and 2007 is presented in Table 62. This table includes both the raw total number of coho counted in the snorkel surveys and the calibrated total number of coho.

Table 62. Summary of coho snorkel counts in Olema Creek, 2003-2007.

Year	Total Survey Length (km)	Total Habitat Units	Number of Pools			Coho Counted	
			Total	Snorkeled	w/ Coho	Raw	Calibrated
2003	8.1	459	184	46	44	2,153	1,995
2004	12.6	862	363	78	77	5,746	5,390
2005	11.9	671	318	74	74	8,586	6,381
2006	11.6	859	324	75	52	397	415
2007	11.8	917	368	89	86	6,688	7,724

3.16.3 Coho Basinwide Estimate

Coho densities (by both pool length and calibrated pool surface area) and a population estimate with 95% confidence interval were calculated for the coho survey area, and are shown in Table 63. The 2007 coho population estimate for Olema Creek is 31,936 ± 4,122. This was the highest population estimate for Olema Creek since monitoring began in 2003. In previous years, the population estimates have ranged from 1,793 (± 869) juveniles in 2006 to 27,423 (± 7,772) juveniles in 2005.

Table 63. Coho density, population estimates, and condfidence intervals (CI), Olema Creek coho survey area, 2003-2007.

Year	Total Survey Length (km)	Avg. Coho Per Pool		Density		Population Estimate	Variance	95% CI
		Raw	Calibrated	coho/m	Coho/m^2			
2003	8.1	46.79	43.36	1.934	0.441	11,926	2,057,080	± 3,244
2004	12.6	83.28	78.12	3.658	0.835	25,857	488,082	± 1,499
2005	11.9	116.03	86.23	3.301	0.936	27,423	13,568,576	± 7,772
2006	11.6	5.29	5.53	0.301	0.093	1,793	169,577	± 869
2007	11.8	75.15	86.78	4.247	1.295	31,936	3,950,948	± 4,122

3.17 Pine Gulch Creek Juvenile Coho Basinwide Survey Summary

Both the 2007 summer habitat and basinwide snorkel surveys of Pine Gulch Creek were initiated at monument tag 00, at the bridge within the Marin County Open Space District, and continued upstream to monument tag 95, above the Texeira ranch within the Point Reyes National Seashore. The measured basinwide habitat survey length for the main channel was 10.3 km.

3.17.1 Habitat Survey

In 2007, a total of 860 mainstem habitat units were identified in the 10.3 km Pine Gulch Creek survey area. Pool and riffle units comprised the majority of the habitat types measuring a total of 8.3 km. Overall habitat composition was 39% pool, 40% riffle, and 21% flatwater (Table 64). Side channel and backwater units were also measured but not incorporated into the basinwide habitat analysis. Flatwater and riffle habitat types made up 91% of the total side channel habitat composition. Overall, 823 meters of side channel habitat and 147 meters of backwater habitat units were measured during the basinwide habitat survey.

Table 64. Habitat composition of Pine Gulch coho survey area, 2001-2006 average and 2007.

Unit type	Average 2001-2006		2007	
	Length of Units (m)	%	Length of Units (m)	%
Pool	4,463	50	4,833	47
Flatwater	1,677	19	1,972	19
Riffle	2,710	31	3,470	34
Total	**8,850**		**10,275**	

Our observations indicate that side channel and backwater habitat (Table 65) may influence the success of emergent fry, especially during higher spring flow events. Our monitoring has been able to correlate a relationship between % side channel and backwater habitat, and observed egg to juvenile survival rates.

Table 65. Summer off channel habitat densities of the Pine Gulch mainstem, 2004-2007.

Unit type	2005		2006		2007	
	Length (m)	Density (m per 100m)	Length (m)	Density (m per 100m)	Length (m)	Density (m per 100m)
Side Channel	579.1	5.94	764.8	7.57	823.3	7.99
Backwater	23.9	0.24	241.4	2.39	147.3	1.43
Survey length*	9.8 km		10.1 km		10.3 km	

*Survey lengths are based on established monument tags for comparison between years.

Woody debris information is collected during the basinwide habitat survey is summarized for 2005-2007 (Table 66) and may be used to identify trends in woody debris availability and recruitment trends over time. Within Pine Gulch Creek, the density of woody debris pieces per 100 meters has been reducing over the past three years of survey, with the density of root wads, SWD jams and LWD jams increasing during that same period.

Table 66. Summary of basinwide instream woody debris per 100 meters of Pine Gulch mainstem during summer baseflow conditions including rootwads, large woody debris (LWD) jams, small woody debris (SWD) jams, and woody debris (WD) in 10-20 cm, 20-50 cm and greater than 50 dcm catagories.

Field season	Survey Length (# 100 m sections)	Rootwads Density per 100 m	LWD jams Density per 100 m	SWD jams Density per 100 m	10-20cm WD Density per 100 m	20-50cm WD Density per 100 m	>50cm WD Density per 100 m
2005	105.2	0.8	0.4	0.8	6.0	4.8	1.1
2006	111.2	1.2	0.5	1.1	3.3	3.5	1.2
2007	112.5	1.2	0.5	1.4	2.7	3.3	0.4

3.17.2 Snorkel Counts

A total of 860 habitat units were delineated within the 10.3 km Pine Gulch Creek snorkel survey area with pool units representing 39% of all surveyed units. Snorkel surveys were conducted on 28% of the delineated pools. No coho were observed in any of the 95 snorkeled pools. Historically, coho have been present within 20% to 63% of the pools snorkeled. Sixteen of the 95 snorkeled pools (16.8%) were electrofished within a day following the snorkel counts. No coho salmon were detected throughout the electrofishing surveys on Pine Gulch. A summary of the Pine Gulch Creek snorkel surveys is presented in Table 67.

Table 67. Summary of coho snorkel counts in Pine Gulch Creek, 2001-2007.

Year	Total Survey Length (km)	Total Habitat Units	Number of pools			Coho Counted	
			Total	Snorkeled	w/ Coho	Raw	Calibrated
2001	7.4	550	266	68	28	152	162
2002	9.0	662	302	64	39	239	271
2003	7.7	514	218	49	26	85	110
2004	9.1	606	351	57	13	21	11*
2005	9.8	614	309	67	42	219	249
2006	10.1	821	357	104	21	58	86
2007	10.3	860	339	95	0	0	0

3.17.3 Coho Basinwide Estimate

The 2007 basinwide estimate for coho salmon in Pine Gulch Creek is zero, based on extensive electrofishing and snorkeling effort distributed throughout the watershed. Historical density and population estimates are presented in Table 68. In previous years the population estimate has ranged from 108 juveniles in 2004 to 1,205 (± 337) juveniles in 2002. This year class was extremely weak in 2004, with a total juvenile estimate of only 108 coho. In spring 2005, only eight coho smolts were observed leaving the watershed, and likelihood of adult returns was negligible, without straying from other watersheds.

Table 68. Coho density, population estimates, and confidence intervals (CI); Pine Gulch coho survey area, 2001-2007.

Year	Total Survey Length (km)	Avg. Coho per Pool		Density		Population Estimate	Variance	95% CI
		Raw	Calibrated	Coho/m	Coho/m^2			
2001	7.4	2.24	2.38	.1475	0.0452	589	24,104	± 329
2002	9.0	3.73	4.23	.2634	0.0786	1,205	25,232	± 337
2003	7.7	1.73	2.24	.1407	0.0411	585	11,772	± 236
2004	9.1	0.37	0.19*	.0133*	0.0039*	108	N/A	N/A
2005	9.8	3.27	3.72	.2188	0.0721	1,150	66,615	± 554
2006	10.1	0.56	0.83	.0739	0.0301	295	9,419	± 201
2007	10.3	0	N/A	N/A	N/A	N/A	N/A	N/A

* Not used for population estimate or reporting due to low confidence in electrofishing efficiency.

3.18 Redwood Creek Juvenile Coho Basinwide survey Summary

The 2007 summer habitat survey of Redwood Creek was initiated at the base of Big Lagoon at Muir Beach and continued upstream to monument tag 74, within the Mt. Tamalpais State Park. The measured basinwide survey length for the main channel was 8.5 km.

Basinwide snorkel surveys were conducted on 8.1 km of the Redwood Creek mainstem starting at the downstream migrant trapping location adjacent to the Muir Beach parking lot and ending within the Mt. Tamalpais State Park. Improved water quality conditions below the Pacific Way bridge allowed for the implementation of snorkel surveys beginning at the downstream migrant trapping location.

3.18.1 Habitat Survey

In 2007, a total of 614 mainstem habitat units were identified within the 8.5 km Redwood Creek survey area. Pool units were the primary habitat type measuring a total of 4.9 km. Overall habitat composition was 44% pool, 35% riffle, and 21% flatwater (Table 69). One dry section of streambed accounted for only 7 meters of the total habitat length surveyed. Side channel and backwater units were also measured but not incorporated into the basinwide habitat analysis. Flatwater and riffle habitat types accounted for the entire side channel habitat composition. Overall, 199 meters of side channel habitat and 126 meters of backwater habitat units were measured during the basinwide habitat survey.

Table 69. Habitat composition of Redwood Creek coho survey area, 1998, 2004-2006 average and 2007.

Unit type	Average 1998, 2004-2006		2007	
	Length of Units (m)	%	Length of Units (m)	%
Pool	4,422	54	4,925	58
Flatwater	1,779	22	1,463	17
Riffle	1,934	24	2,076	25
Total	8,134		8,464	

Our observations indicate that side channel and backwater habitat (Table 70) may influence the success of emergent fry, especially during higher spring flow events. Our monitoring has been able to correlate a relationship between % side channel and backwater habitat, and observed egg to juvenile survival rates.

As an example, on Redwood Creek, the estimated egg to juvenile survival rate, with the exception of summer 2007 (accepted as a very dry spring) was 4-7%, while in Olema and Pine Gulch Creek, for the same period of time, the egg to juvenile survival rate was 11-17%. Observations show that the average density of side channel and backwater habitat for Redwood Creek is about 50% of that observed in Olema and Pine Gulch Creek. Further support for this theory is the fact that the survey period of 2004-2006 represented normal to high rainfall and runoff years (including high spring flows). During those years, Redwood juvenile survival rates were low. In 2007, where the spring was well below normal rainfall totals, the Redwood Creek egg to juvenile survival was comparable to observed rates in these other watersheds.

Table 70. Summer off channel habitat densities of the Redwood Creek mainstem, 2004-2007.

Unit type	2004		2005		2006		2007	
	Length (m)	Density (m per 100m)	Length (m)	Density (m per 100m)	Length (m)	Density (m per 100m)	Length (m)	Density (m per 100m)
Side Channel	277.3	3.65	401.6	4.46	257.3	3.06	199.45	2.35
Backwater	12.5	0.16	6.8	0.08	153.1	1.82	126.3	1.49
Survey length*	7.6 km		9.0 km		8.4 km		8.5 km	

*Survey lengths are based on established monument tags for comparison between years.

In addition to habitat, woody debris information is collected during the basinwide habitat survey is summarized for 2005-2007 (Table 71) and may be used to identify trends in woody debris availability and recruitment trends over time. Within Redwood Creek, the density of root wads Large Wood and LWD jams has generally increased over the past three years, while all other metric densities are generally reduced.

Table 71. Summary of basinwide instream woody debris per 100 meters for Redwood Creek mainstem during summer baseflow conditions including rootwads, large woody debris (LWD) jams, small woody debris (SWD) jams, and woody debris (WD) in 10-20 cm, 20-50 cm and greater than 50 dcm catagories.

Field Season	Survey Length (# 100 m sections)	Rootwads Density per 100 m	LWD Jams Density per 100 m	SWD Jams Density per 100 m	10-20cm WD Density per 100 m	20-50cm WD Density per 100 m	>50cm WD Density per 100 m
2005	94.7	0.6	0.5	0.9	4.5	2.8	0.5
2006	88.5	0.6	0.4	0.6	3.1	2.6	1.1
2007	88.0	1.1	0.6	0.7	2.7	2.3	0.8

3.18.2 Snorkel Counts

A total of 598 habitat units were delineated within the 8.1 km Redwood Creek snorkel survey area with pool units representing 44% of all surveyed units. Snorkel surveys were conducted on 31% of the delineated pools with coho being observed in 91% of the sampled pools. A total of 1,976 coho were counted in the 81 snorkeled pools, giving a raw average of 24.40 coho per pool.

A summary of the snorkel counts for Redwood Creek is presented in Table 72. This table includes both the raw total number of coho counted in the snorkel surveys and the calibrated total number of coho.

Table 72. Summary of coho snorkel counts in Redwood Creek, 1998, 2004-2007.

Year	Total Survey Length (km)	Total Habitat Units	Number of Pools			Coho Counted	
			Total	Snorkeled	w/ Coho	Raw	Calibrated
1998	7.6	500	260	144	119	1,984	1,678
2004	7.8	499	171	55	54	2,138	2,063
2005	7.7	423	193	61	61	2,737	2,716
2006	7.7	536	228	63	35	198	290
2007	8.1	598	262	81	74	1,976	2,421

3.18.3 Coho Basinwide Estimate

Coho densities (by both pool length and calibrated pool surface area) and a population estimate with 95% confidence interval were calculated for the coho survey area, and are shown in Table 73. The 2007 coho population estimate for Redwood Creek is 7,832 ± 1,640. This was a slight increase from from 2004, which is the same year class. In previous years, the population estimate ranged from 1,050 (± 486) juveniles in 2006 to 8,594 (± 1,652) juveniles in 2005.

Table 73. Coho density, population estimates, and confidence intervals (CI); Redwood Creek coho survey area, 1998, 2004-2007.

Year	Total Survey Length (km)	Avg. Coho per Pool		Density		Population Estimate	Variance	95% CI
		Raw	Calibrated	Coho/m	Coho/m^2			
1998	7.6	13.78	11.65	0.662	0.162	3,029	51,134	± 455
2004	7.8	38.87	37.51	2.61	0.693	6,415	400,236	± 1,367
2005	7.7	44.87	44.53	1.937	0.458	8,594	606,987	± 1,652
2006	7.7	3.14	4.61	0.302	0.073	1,050	54,241	± 486
2007	8.1	24.40	29.89	1.813	0.473	7,832	621,780	± 1,640

3.19 GSS Survey Summary

GSS surveys were conducted in tributaries where water quality constraints made snorkel surveys infeasible. For each GSS monitoring reach, a basinwide habitat survey was conducted. Every fifth pool unit was selected and sampled in order to obtain a 20% subsample of delineated pool habitats. Selected pools were sampled using electrofishing or seine techniques and established fish processing techniques. When high densities of fish were present in a pool, the units were seined previous to electrofishing to reduce potential for electrofishing injuries. For Quarry Gulch, seine techniques were employed in areas of known California red-legged frog habitat. For more complete results of the GSS survey, please refer to Appendix B.

Three tributaries in Olema Creek were sampled: John West Fork, Giacomini Creek, and Quarry Gulch. The combined contribution of these three tributaries to the Olema Creek juvenile coho population was estimated to be 2,225 ± 675 juveniles in 2007 (basinwide estimate was 31,936 ± 4,122). Of that total, John West Fork contributed 93% of the estimated population. When combined with the mainstem population estimate, the total watershed population estimate is 34,161 juveniles, with John West Fork contributing 6% of the total, and the other two tributaries adding only 0.5% of the total population estimate.

The fork lengths for coho sampled on the three tributaries ranged from 44 to 86 mm on John West Fork, 35 to 92 mm on Giacomini Creek, and 49 to 76 mm on Quarry Gulch. It should be noted that sampling in these tributaries occurred in June, rather early in the summer season. For

fork length frequencies and weight-length relationships, please refer to Appendix B, Figures B2-B5, B7-B10, and B12-B15. K factors were also determined for the three tributaries, with the lowest K factor found on Giacomini Creek (0.96) and the highest K factor found on Quarry Gulch (1.02). For complete tables of K factors (2005-2007) please refer to Appendix B, Tables B1-B3, B6-B8, and B10-B12.

Cheda Creek is a tributary to Lagunitas Creek. In 2000, a large habitat restoration project took place below a cattle crossing on Cheda Creek, resulting in new habitat and easier access for spawning adults. Because of this restoration project, Cheda Creek can be viewed as an example of a post-restoration creek. Summer monitoring began in 2005. In 2007, the population estimate for Cheda Creek was 589 ± 202 juveniles. The coho fork lengths measured at Cheda Creek ranged from 36 mm to 81 mm. For fork length frequencies and weight-length relationships, please refer to Appendix B, Figures B17-B20. The K factor for Cheda Creek coho was 1.11, which was the lowest K factor for Cheda Creek since monitoring began. For complete K factor tables, please refer to Appendix B, Tables B15-B17.

Bear Valley Creek, another tributary to Lagunitas Creek, was sampled in October 2007. Monitoring was initiated in 2005. In 2007, a single coho juvenile was found on Bear Valley Creek. This coho had a fork length of 97 mm. This was the first time since monitoring began that a coho was found on Bear Valley Creek. For steelhead fork length frequencies and weight-length relationships, please refer to Appendix B, Figures B22 and B23. The coho juvenile had a K factor of 0.99. For complete tables of K factors, please refer to Appendix B, Tables B20-B22.

4 - Discussion

4.1 Multiple Life Stage Comparisons

Through multiple life stage monitoring, the NPS is able to develop survival estimates for each stage of the coho life history. While we are able to derive an extrapolated survival rate estimate using this method, we still do not have a means of developing a confidence interval at this time.

Analysis of these integrated data allow for two types of summary analyses. These monitoring methods support a means of tracking survival rates between life stages. When compared between watersheds, we are able to identify if observed trends between life stages are likely based on localized or regional conditions. The analyses of these data also allow for comparison to determine whether the observed results are dependent on year class conditions, or habitat conditions. In cases where habitat is limiting, then we would predict that results would be observed on an annual basis.

Tables 74, 75, and 76 represent life stage comparisons and survival rates for coho salmon within Olema Creek, Pine Gulch, and Redwood Creek respectively. Figure 73 provides a graphical representation of the population fluctuations in 2003-2004 year class for Olema, Pine Gulch, and Redwood Creeks thru the life cycle of the cohort.

Table 74. A comparison of multiple life stage observations of coho salmon within the Olema Creek mainstem from spawner years (SY) 2002-2003 to SY 2006-2007.

Olema Creek Mainstem (watershed)*	Spawner Year (SY) 2002-2003	2003-2004	2004-2005	2005-2006	2006-2007
PLD Index	20	138	184	12	80
Redds	10 [a]	88	92	6[a]	66
(watershed redd total)*	(22)	(109)	(137)	(10)	(95)
Average Female Fork Length	64[b]	66.3	65.7	58.7	65.3
Estimated Number of Eggs	23,580[c]	230,202[c]	234,317[c]	10,973[c]	165,106[c]
Basinwide Juvenile Estimate	11,926±3,244	25,857±1,499	27,423±7,772	1,793 ±869	31,936±4,122
Estimated Survival Rate Egg to Juvenile	50.6%	11.2%	11.7%	16.3%	19.3%
Watershed Smolt Production Estimate	831±167	1,296±724 [d]	10,544±8,399	1,098±116	-
Mean Smolt Length (mm)	114.31	116.05	98.94	116.43	
Mean Smolt Weight (g)	15.11	15.95	10.28	14.72	
Estimated Survival Rate Juvenile To Smolt	7.0%	5.0%	38.4%	61.2%	-
Estimated Survival Rate Egg To Smolt	3.5%	0.6%	4.5%	30.0%	-
Estimated Survival Rate Smolt To Adult[e]	2.40%	14.66% [d]	SY2007-2008[f]	SY2008-2009[f]	SY2009-2010[f]

*Includes John West Fork redd count

[a]Due to poor observer efficiency, the PLD index was used to estimate the Olema mainstem redd count based on two spawners per redd.

[b]Average female length based on female carcass lengths on Olema Creek for spawner years 2003-2004 thru 2006-2007.

[c]Estimated number of eggs using Shapovalov and Taft (1954) formula based on average female fork length.

[d]The Spawner Year 2003-2004 watershed production estimate is artificially low since trapping operations were suspended early due to the capture of Red-legged frog tadpoles. The actual watershed production estimate was likely four to five times higher based on regional smolt production estimates. For these reasons, the smolt to adult survival rate is likely artificially high.

[e]Estimated smolt to adult calculated by dividing number of adult spawners (estimated based on 2 times the total watershed redd count [in parentheses]) divided by the estimated number of outmigrating smolts for previous cohort.

[f] Survival rate will be determined after adults return during the indicated spawner year (SY).

Table 75. A comparison of multiple life stage observations of coho salmon within the Pine Gulch Creek mainstem from spawner years (SY) 2000-2001 to SY 2006-2007.

Life Stage Observation	Spawner Year (SY)						
	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007
PLD Index	1	2	2	0	3	0	0
Redds	1	2	1	1	3	1	0
Average Female Fork Length	62.5 [a]	62.5 [a]	62.5 [a]	62.5 [a]	62.5 [a]	62.5 [a]	-
Estimated Number of Eggs	2,199 [b]	4,398 [b]	2,199 [b]	2,199 [b]	6,597 [b]	2,199[b]	-
Basinwide Juvenile Estimate	589±236	1,205±337	585±236	108	1,150±554	295 ±201	0
Estimated Survival Rate Egg to Juvenile	26.8%	27.4%	26.6%	4.9%	17.4%	13.4%	-
Watershed Smolt Production Estimate	-	-	737±144	10	368±76	219±33	-
Mean Smolt Length (mm)	113.32	111.54	111.8	112.5	99.63	112.98	
Mean Smolt Weight (g)	14.31	14.03	14.01	14.33	9.78	13.57	
Estimated Survival Rate Juvenile to Smolt	-	-	N/A	9.3%	32.0%	74.2%	-
Estimated Survival Rate Egg to Smolt	-	-	33.5%	4.6%	5.6%	10.0%	-
Estimated Survival Rate Smolt to Adult[c]			0.27%	0%	SY2007-2008[d]	SY2008-2009[d]	SY2009-2010[d]

[a]Average female length based on female carcass lengths on Redwood Creek for spawner years 1997-1998 thru 2004-2005.
[b]Estimated number of eggs using Shapovalov and Taft (1954) formula based on average female fork length
[c]Estimated smolt to adult calculated by dividing number of adult spawners (estimated based on 2 times the redd count) divided by the estimated number of outmigrating smolts for previous cohort
[d] Survival rate will be determined after adults return during the indicated spawner year (SY).

Table 76. A comparison of multiple life stage observations of coho salmon within the Redwood Creek mainstem from the SY 2003-2004 to SY 2006-2007.

Life Stage Observation	Spawner Year (SY)			
	2003-2004	2004-2005	2005-2006	2006-2007
PLD Index	67	171	27	28
Redds	43	93	12	21
Average Female Fork Length	64.2	63.3	62	66
Estimated Number of Eggs	102,328[a]	212,315[a]	25,774[a]	54,207[a]
Basinwide Juvenile Estimate	6,415±1367	8,594 ± 1,652	1,050±486	7,832 ±1,640
Estimated Survival Rate Egg to Juvenile	7.0%	4.0%	4.1%	14.4%
Watershed Smolt Production Estimate	2,481±616	3,253 ±542	520 ±126	-
Mean Smolt Length (mm)	100.51	97.69	115.28	
Mean Smolt Weight (g)	10.58	9.26	14.16	
Estimated Survival Rate Juvenile to Smolt	34.8%	37.9%	49.5%	-
Estimated Survival Rate Egg to Smolt	2.4%	1.5%	2.0%	-
Estimated Survival Rate Smolt to Adult[b]	1.69%	SY2007-2008 [c]	SY2008-2009 [c]	SY2009-2010 [c]

[a]Estimated number of eggs using Shapovalov and Taft (1954) formula based on average female fork length.
[b]Estimated smolt to adult calculated by dividing number of adult spawners (estimated based on 2 times the redd count) divided by the estimated number of outmigrating smolts for previous cohort.
[c] Survival rate will be determined after adults return during the indicated spawner year (SY).

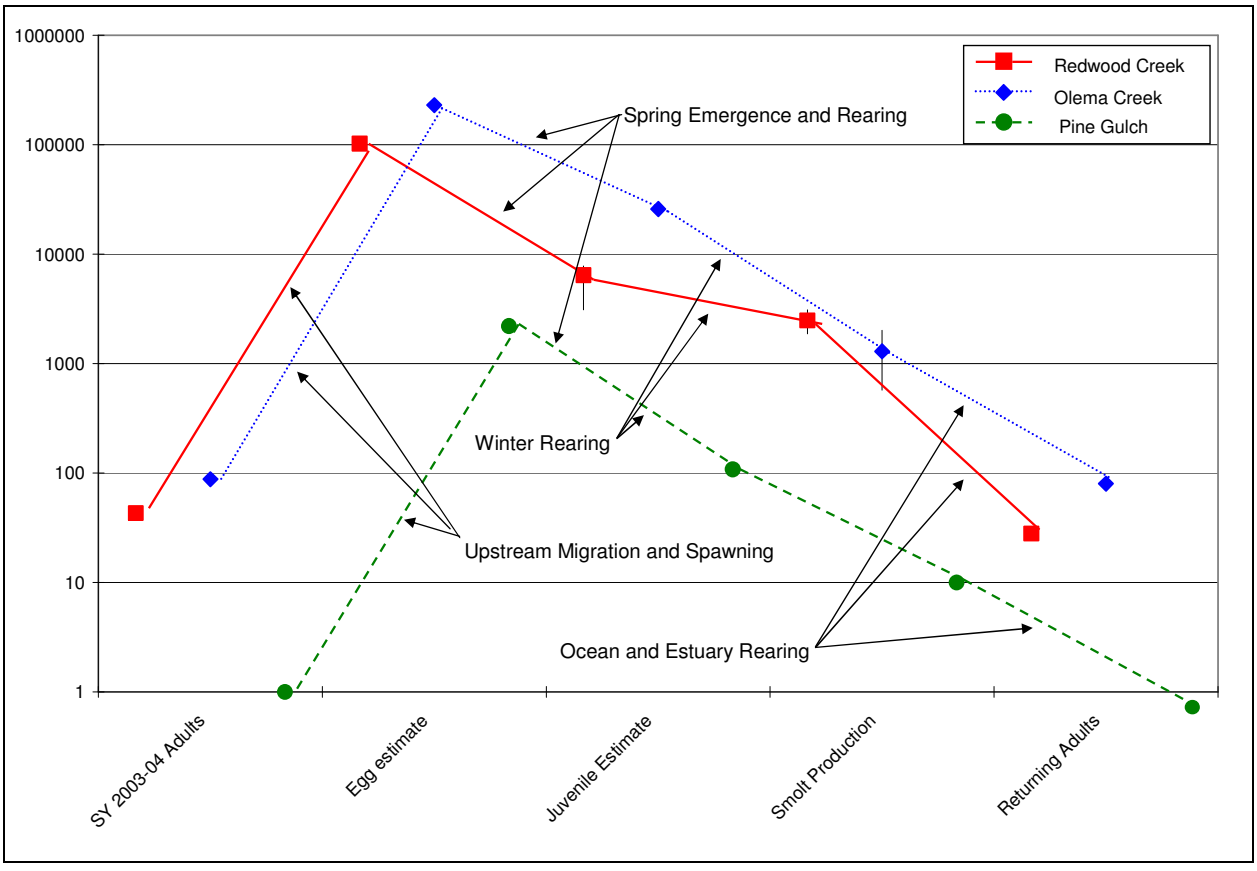


Figure 73. Survival rate between monitored life stages in Olema, Pine Gulch, and Redwood Creeks for spawner year 2003-2004. should be noted that the Olema Creek smolt trap was removed approximately one month early during the spring of 2005 and therefore the 2005 smolt production estimate is likely much smaller than the true production.

4.1.1 Coastal Marin Watershed Observations

Egg to Juvenile Survival: The egg-juvenile survival rates may be used to understand habitat differences between monitored watersheds. The egg to juvenile survival rate is calculated from the estimated number of eggs and the basinwide juvenile estimate conducted in the fall of the following summer. The egg estimate is determined from number of documented redds times the estimated number of eggs per female using the Shapavolov and Taft (1954) formula based on female fork length (where the average female fork length for that year).

Factors that may affect the rate of egg to juvenile survival include winter and spring peak discharge events, redd scour, and side channel/backwater habitat availability for newly emerged juveniles. Estimated egg to juvenile survival has ranged from 11 – 19% in Olema Creek (SY 2003-2004 to SY 2006-2007), 5-27% in Pine Gulch Creek (SY 2000-2001 to SY 2006-2007), and 4-14% in Redwood Creek (SY 2003-2004 to SY 2006-2007). The variability in Pine Gulch Creek may be accounted for by the very small population size and low spawner detection levels (maximum number of redds detected in the watershed is 3). The 2002-2003 spawner year survival rate (51%) on Olema Creek is most likely an over estimate of the juvenile survival caused by low redd detection levels during the 2002-2003 spawning season and will be excluded from all subsequent analysis.

In Lagunitas Creek, MMWD has developed a predictive model to estimate the number of juveniles that will be observed during summer sampling, based on the number of redds and peak April discharge (Stillwater Sciences 2008). This best-fit model indicates that summer survival is highly dependent on spring runoff conditions, likely during the time of newly emergent fry (March – April). Side channel and backwater habitat availability is likely important for fry when they are newly emerged and most susceptible to higer flows.

In summer 2007, above average egg-juvenile survival was observed in both Olema (4% higher than average) and Redwood (7% higher than average) Creeks for the progeny of the 2006-2007 spawner year. The increased survival rates are likely due to the mild spring experienced during the spring of 2007. With less than four inches of rain received from March through April, newly emerged coho fry did not have to use excessive amounts of energy to combat high water velocities during spring storm events. The mild spring allowed coho fry to actively feed and rear in pool habitats with low water velocities. In Pine Gulch a survival estimate was not obtained due to the absence of coho fry in the watershed.

Our investigations have raised a question about egg-juvenile survival rates between Olema and Redwood Creek. During the past four years of monitoring, Redwood Creek has had a lower egg-juvenile survival rate than Olema Creek. Information provided by Kamman Hydrology and Engineering, Inc and the NPS has indicated channel confinement in lower Redwood Creek (Jones and Stokes 2007). The channel is also confined in upper Redwood Creek through Muir Woods National Monument where historic bank armoring was installed by the Civilian Conservation Corps. The Redwood Creek estuary known as “Big Lagoon” is a fraction of its historic size and provides limited habitat for salmonids before entering the Pacific Ocean.

The lack of emergent fry habitat is further supported by coho fry captures at the Redwood Creek downstream migrant trap during the spring of 2005 and 2006 and NOAA fisheries estuary monitoring work in 2004 and 2005. Coho fry captures in the downstream extent of the watershed suggests that a large number of coho fry are prematurely forced downstream due to the lack of available refugia during spring storm events. Recent restoration projects on Redwood Creek,

including Phase I and II of the Banducci reach, as well as the proposed Big Lagoon restoration, have been designed to expand and enhance side channel and backwater habitat to reduce this potential habitat and population constraint.

Juvenile to Smolt Survival: The juvenile to smolt survival rate is determined based on the fall basinwide population estimate divided by the spring outmigration estimate documented the following spring. The juvenile to smolt survival rate is indicative of the overwinter survival, and may reflect on the availability of overwintering habitat within the watershed. Spring outmigrant trapping is problematic to conduct. High spring flows often wash out the trap, resulting in missed monitoring days. In these cases, the smolt trapping often underestimates the rate of outmigration, however it remains an important aggregate measure of watershed habitat quality. In addition, aggregate smolt size information, including average fork length and weight of outmigrating coho salmon indicate differences between watershed, which is important with respect to ocean survival and adult returns.

Factors that may affect the rate of juvenile to smolt survival include winter and spring peak discharge events and overwintering (floodplain refugia). Estimated juvenile to smolt survival has ranged from 4 – 61% in Olema Creek (SY 2002-2003 to SY 2005-2006), 9-74% in Pine Gulch Creek (SY 2003-2004 to SY 2005-2006), and 34-50% in Redwood Creek (SY 2003-2004 to SY 2005-2006). The variability in Pine Gulch Creek may be accounted for by the very small population size.

During the spring of 2007, all three monitored watersheds experienced a much higher juvenile-smolt survival rate than in previous years. The highest survival rate was observed in Pine Gulch with an estimated survival rate of 74.2% while the lowest survival rate was observed in Redwood Creek with an estimated survival rate of 49.5%.

During the winter 2006-2007, Marin County experienced below average rainfall receiving only 29 inches of rain compared to the average of 39 inches per year. The mild winter meant that juvenile coho were able to feed and rear in pools with low velocities for a longer period of time than in normal years. For example, on Redwood Creek juvenile coho grew an average of 36.79 mm and 8.61 grams from the summer of 2006 to the spring of 2007 when they were leaving as smolts. In 2007, the size of coho outmigrating smolts leaving Redwood Creek was nearly 8mm longer and 3 grams heavier than the average from the previous two years of smolt trapping. This larger smolt size may correlate with the milder winter, allowing for more feeding opportunities and less stress on fish as they overwintered. With an average egg-juvenile survival rate and an above average juvenile-smolt survival rate, the struggling 2005-2006 spawner year may have a chance at rebounding to average escapement levels. Whether or not the population is able to rebound in spawner year 2008-2009 is largely dependent on the summer 2007 ocean productivity conditions.

Smolt to Adult Survival: The smolt to adult survival estimates correlate with the ocean phase of the coho salmon life-cycle. The smolt condition factors, including length and weight, at the time of outmigration, as well as the estuarine habitat condition and availability at the mouth of these watersheds likely affects the adult returns. In addition, the ocean productivity metrics that have been developed and refined over the past decade have dramatically increased the ability of scientists to be predictive about the ocean conditions and therefore potential rates of return for these salmonid populations. In both 2005 and 2006, it has been documented that the ocean conditions in the Central California coast area were abnormal, with warmer water conditions

leading to reduced upwelling throughout the region. In future years, the smolt to adult survival may be analyzed against documented ocean indicators.

The 2006-2007 adult returns were reduced from the previous return of this year class. In Olema Creek, the mainstem experienced a 25% decline in coho redds for the 2006-2007 year class compared to 2003-2004, while the John West Fork showed a 28% increase in redds. Total Olema Creek watershed redd numbers, which takes into account John West Fork, declined by 13%. Redwood Creek mainstem had a 51% decline in total coho redd production from the previous year class. On Pine Gulch Creek, no spawning activity was observed. Based on smolt production estimates the 2006-2007 year class should have produced strong returns. However, due to poor ocean productivity (CalCOFI 2006) ocean survival rates were low which resulted in only moderate returns.

4.1.2 Olema Creek

The returning 2006-2007 coho salmon year class showed a 13% decline in redd production in the Olema Creek watershed between SY2003-2004 and SY2006-2007 (Del Real et al. 2007). However, summer estimates indicate that the spawning production, in combination with a very mild winter, resulted in high juvenile densities and a basinwide population estimate showed an approximate 19% increase from the 2003-2004 year class estimate (see Table 74).

The estimated survival rates for smolts (see Table 74), including juvenile to smolt and smolt to adult are likely affected by difficult trapping conditions in spring 2005. Trapping limitations included the following: late trap installation (2 weeks late); closure due to high flows (9 days of the 54 day trapping period); and early closure due to presence of California red-legged frog (federally threatened species). As a result, the juvenile to smolt survival rate represents an underestimate, while the smolt to adult survival rate is likely an overestimate. The results reported for Olema Creek include a summer juvenile coho population estimate of 31,936 ± 4,122 for the mainstem section extending from the Vivekananda Bridge to Randall Gulch at stream km 15.0. This represents a large portion of the perennial stream habitat in Olema Creek. Electrofishing and snorkel surveys produced juvenile coho densities that were comparable. As an example, in 2007, the juvenile coho salmon density of 4.01 (±0.32) fish/meter and 0.97 (±0.08) fish/meter^2 for the 16 index reach pools is comparable to the density of 4.25 fish/meter and 1.30 fish/meter^2 in the 89 basinwide snorkel survey pools (see Table 36, page 96 and Table 63, page 125).

Steelhead young-of-year were found in all habitats with highest densities observed in riffle habitat, 7.25 (±1.10) fish/meter compared to 1.39 (±0.23) fish/meter observed in pool habitat. This may be indicative of high coho densities in pool habitat. Because steelhead are less discriminating about depth as a feature of habitat choice, and therefore, tend to occur in most stream habitat, even at very shallow depths. This is reasonable considering the differences between pool and riffle are depth and velocity.

The 2006-207 Escapement Report noted a 13% decline in redd production in the Olema Creek watershed between SY2003-204 and SY2006-207 (Del Real et al. 2007). Despite this observation, summer 2007 surveys indicate the highest population estimate for Olema Creek in the 5 years of basinwide surveys. The high summer juvenile estimate reflects a calm spring weather pattern and increased survival associated with a normal 2006-207 escapement. Summer 2007 represented the third summer juvenile survey for this coho year class. In all three generations of this coho cohort, densities of coho salmon in pools have ranged from 2.5 to 4.26

fish per meter (see Table 36, page 96), representing healthy stream densities. Though this progress report only allows for description of two generations based on basinwide results, the results of the index reach surveys indicate stability in the 2007 coho year class in Olema Creek.

4.1.3 Pine Gulch Creek

There were no observed coho in Pine Gulch Creek in the summer of 2007. This corresponds with the lack of observed adult spawning behavior during the winter of 2006-2007, and likely represents the result of a very small coho spawning population in the watershed. Based upon our observations, Pine Gulch Creek has very good habitat and has supported high levels of winter survival as reported in the 2002 monitoring report (Ketcham and Brown 2003). This high overwinter survival is indicative of good habitat conditions, including deep and well-structured pool habitat.

The 2007 summer surveys would have been the third returning generation of the first observed coho in Pine Gulch Creek. In 2004, the number of coho observed was so limited that a population estimate could not be made, and the raw count (108) from the snorkel surveys was reported. The subsequent spring, only 10 coho smolts were observed leaving the watershed. The results of both index reach surveys and basinwide estimates indicated severe declines in this year class, and with such a low estimated outmigration, it is not suprising that no coho were documented in 2007.

The presence and persistence of coho for a second generation shows that Pine Gulch Creek has the capacity to support coho, however the initial number of fish was likely so small, and interrelated that coho were not able to persist. Other year classes in Pine Gulch will be monitored to determine if they are stable or declining.

4.1.4 Redwood Creek

The returning 2006-2007 coho salmon year class showed a 51% decline in redd production in the Redwood Creek watershed between SY2003-2004 and SY2006-2007 (Del Real et al. 2007). However, summer estimates indicate that the spawning production, in combination with a very mild winter, resulted in high juvenile densities and a basinwide population estimate showed an approximate 18% increase in from the SY2003-2004 year class estimate.

The results reported for Redwood Creek include a summer juvenile coho population estimate of 7,832 ± 1,640 for the mainstem section extending from the Pacific Way Bridge to stream km 7.4. Long-term monitoring in Redwood Creek, Marin County has shown a range in coho per meter from 0.03 to 1.51 in index reach sites monitored between 1988 and 2001 in Redwood Creek (Smith 2001). For the 2007 survey, the NPS observed coho densities of 1.98 coho per meter for pool units surveyed as part of the index reach monitoring program. Overall density by surface area in pools is estimated at 0.52 coho per square meter (see Table 52, page 115).

Though this progress report only allows for description of two generations and the survey reach was 12% longer in 2007, the results of both index reach surveys and basinwide estimates indicate stability in the 2007 coho year class in Redwood Creek.

5 - Conclusion

Coastal Marin County watersheds are some of the most intensely monitored watersheds for coho salmon within the Central California Coast ESU. In addition to our NPS/DFG funded monitoring efforts on Olema Creek, Redwood Creek, Pine Gulch Creek and Cheda Creek, extensive monitoring is conducted by MMWD on Lagunitas Creek, Devils Gulch, and mainstem of San Geronimo Creek, and by the Salmon Protection and Watershed Network (SPAWN) on tributaries of San Geronimo Creek. Through these combined monitoring efforts, we have documented significant information about coho salmon distribution, and use of these small coastal watersheds.

Information summarized in this report shows that the 2006-2007 spawner year class for coho salmon was reduced from the last return of this cohort, with evidence pointing to limited ocean conditions in the spring of 2005 when these fish entered the ocean as smolts. The results also show an effect of environmental conditions. For summer 2007, we observed high rates of egg to juvenile survival (14-19%), for coho juveniles, as well as very high overwintering survival (49-74%) for the smolts outmigrating in spring 2007. These strong rates of survival are likely related to mild winter and dry spring conditions that reduced stress on newly emerged coho fry and overwintering coho juveniles. In fact, despite the lower spawning numbers and redd counts, the summer basinwide estimates exceeded all previous summer estimates in both Olema and Redwood Creek. This year also represented the non-return of coho to Pine Gulch Creek. We have documented that this year class was severely depressed during the last cohort, with only 108 juveniles in summer 2004, and 10 smolts estimated to have left the watershed in spring 2005. Subsequent summer surveys did not document coho juveniles in Pine Gulch Creek.

The intensity of our life-cycle monitoring programs allow for larger scale characterization of patterns observed in the area. Though a relatively small geographic area, the coastal Marin watersheds support a significant proportion of the CCCESU coho salmon, as well as two genetically distinct subpopulations. Genetic evaluations suggest that coho salmon occurring in Olema Creek and Cheda Creek constitute part of the Lagunitas/Olema genetic subgroup that would likely encompass the entire Tomales Bay watershed. Genetic evaluation also suggests that the Pine Gulch Creek population represents an expansion of the Redwood Creek coho population to a new watershed (Garza and Gilbert 2003).

Based on smolt production estimates for this coho salmon cohort, the 2006-2007 year class should have produced strong returns, however only moderate returns were observed. The total Olema Creek watershed redd count, which takes into account John West Fork, declined by 13%. Redwood Creek mainstem had a 51% decline in total coho redd production from the previous year class. Of the four consecutively monitored years of this cohort on Redwood Creek, 2006-2007 had the lowest coho spawning activity. On Pine Gulch, no spawning activity was observed. Cheda Creek, a tributary to Lagunitas Creek, showed a slight increase in redd development along with an increase in returning adult coho spawners.

Our review of redd count and escapement information collected over the past decade indicates annual fluctuations in spawning for each returning cohort in Olema, Cheda, Pine Gulch, and Redwood Creeks.

In Olema Creek monitoring efforts have documented the existence of one weak but consistent year class (SY 1999-2000, 2002-2003, 2005-2006) with an average redd count of 13 redds (6 to 17 redds annually), one variable year class (SY 1998-1999, 2001-2002, 2004-2005, 2007-2008) that had increased in population size to a high of 137 redds, and one consistent year class (SY 1997-1998, 2000-2001, 2003-2004, 2006-2007) with an average redd count of 118 redds (95 to 133 redds annually).

In Redwood Creek monitoring efforts have documented the existence of one weak but consistent year class (SY 1999-2000, 2002-2003, 2005-2006) with an average redd count of 8 redds (5 to 12 redds annually), one highly variable year class (SY 1998-1999, 2001-2002, 2004-2005, 2007-2008) that had increased in population size to a high of 93 redds, and one variable year class (SY 1997-1998, 2000-2001, 2003-2004, 2006-2007) with redd counts ranging from a low of 21 redds to to a high of 80 redds. The last two years, SY 2006-2007 and SY 2005-2006, represent reduced escapement results from previous year classes for all monitored watersheds. We surmise that the strongest year class prior to the 1997-1998 ENSO event, Year Class 3, was severely impacted as fish attempted to overwinter during the El Nino winter.

In Pine Gulch Creek redd detection levels have remained low during all survey years suggesting that this population is still struggling to exist within the Bolinas watershed. In Cheda Creek successful spawning was documented six out of the last seven years since restoration efforts were completed in 2000, proving that this creek provides suitable habitat for coho spawning.

The patterns represented in our monitoring data suggest a regional influence on the coho salmon escapement observed over the past decade. Overall coho escapement within Marin County watersheds has trended upward since the 1997-1998 ENSO event, which likely triggered the Pacific Decadal Oscillation (PDO) shift of dominant productivity from the Alaska Current to the California Current in the late 1990s. From 1999 to 2005, all three coho year classes in Olema Creek and Redwood Creek showed a strong response to these changing ocean productivity patterns. The upward trend was most prominent in the documented return of coho salmon to the Pine Gulch Creek watershed during the winter of 2000-2001. Since 2005 there has been a downward trend in observed coho returns. Based on regional information (MacFarlane et al 2008) and ocean productivity indexes (CalCOFI 2006), poor upwelling along the California coast during summer 2005 and 2006 has resulted in a decrease in ocean productivity within coho ocean rearing grounds. This decrease in ocean productivity has caused a decline in coho returns along the entire CCC ESU. Continued monitoring efforts will allow for better characterization of year classes and annual productivity of coho salmon within coastal Marin County watersheds.

Redd density may be used as a measure for comparison of adult returns within all Marin County monitored watersheds. Redd densities appear to be highly variable from year to year in all of the unregulated streams surveyed in Marin County, while redd counts within Lagunitas Creek, a regulated stream, appear to remain fairly constant with an average of 98 redds (70-139 redds annually). This further supports the relationship of winter flows to spawning success in the coastal streams of Marin County. Total redds observed per watershed in Marin County streams is included as Appendix A - Table A10).

Our data indicate a strong correlation between adult spawner density and the summer juvenile density, suggesting that year class is the dominant factor associated with population observations in these watersheds. Environmental conditions also play a large role in determining juvenile population size and health. For instance, although the 2006-2007 spawner year was only an

average spawner year in terms of run size for both Olema and Redwood Creeks, the summer juvenile coho population estimate for both creeks was one of the largest on record. The 2007 summer population estimate provides insight on how instream conditions can play a vital role in the recovery of the species to historic numbers. Depending on the overwintering survival and ocean conditions, the 2006-2007 year class may have the largest population of all year classes when the cohort returns in during the winter of 2009-2010.

The 2007 smolt production estimates on all three watersheds were much higher than expected based on the juvenile population estimates calculated during the summer of 2006 indicating strong overwinter survival (49.5% to 74% in the three monitored watersheds). This overwinter survival rate is important, given the extremely low summer 2006 juvenile estimates. Hopefully the high survival rate will give this year class the small boost that it needs to start its climb back to recovery.

This summary also documents extensive information on size and weight of outmigrating coho salmon observed leaving the monitored watersheds. Smolt size is directly related to ocean survival (Miller and Sandros 2003) with smolts being of larger size at time of ocean entrance having a higher chance at surviving to adult. Based on these data we have identified that the spring 2006 outmigrants from all watersheds were approximately 10 mm and 3 grams smaller than average when compared with other years. Second, Redwood Creek tends to have smaller smolt outmigration sizes than smolts observed leaving the Olema and Pine Gulch Creek watersheds. Comprehensive smolt trapping is in its fourth year of operation at all these watersheds. Additional years of data will help refine the general size of smolts leaving these coastal Marin watersheds.

In 2007, smolts captured in Redwood Creek during the spring of 2007 were 8mm longer and 3 grams heavier than the average from the previous two years. This increase in smolt size raises the question of whether fish observed in 2005 and 2006 were small, or if the smolts observed in 2007 were larger than normal. One hypothesis is that with the decrease in intraspecies competition juvenile coho fry were able to obtain food while expending less energy fighting for instream position. Another possible reason may lie in the relationship between storm events and available cover during high flow events. Since the winter of 2006-2007 was much milder than previous years, juvenile coho spent less time fighting to hold position within the stream and more time actively feeding. However, the increased smolt size on Redwood Creek in 2007 was average when compared to regional data. This suggests that in most years the coho being produced from Redwood Creek have a smaller chance of surving through their ocean life stage then other coho populations in the region.

6 - Literature Cited

Adams, D., S. Allen, J. Bjork, M. Cooprider, A. Fesnock, M. Koenen, T. Leatherman, S. O'Neil, D. Press, D. Schirokauer, B. Welch, and B. Witcher. 2006. San Francisco Bay Area Network Vital Signs Monitoring Plan. NPS/SFAN/NRR—2006/017 National Park Service, Fort Collins, Colorado.

Anderson, D. and H. McGuire. 1994. Redwood Creek basin 1991-1992 spawning and carcass survey, annual report. Unpublished report. National Park Service, Redwood National Park. Arcata, California.

Barrineau, C. E. and S. P. Gallagher. 2001. Noyo River fyke/pipe trap checking protocol. California State Department of Fish and Game. Steelhead Research and Monitoring Program, 1031 South Main, Suite A, Fort Bragg, California 95437. Report FB-07.

Beamish, S.S. 2000. Determining the significance of habitat on coho salmon and steelhead trout in the Olema Creek watershed. Masters Project. Nicholas School of the Environment. Duke University.

Beidler, W. M. and T. E. Nickelson. 1980. An evaluation of the Oregon Department of Fish and Wildlife standard spawning fish survey system for coho salmon. Oregon Department of Fish and Wildlife Information Report Series, Fisheries Number 80-9.

Bjorkstedt, E.P. 2000. DARR (Darroch Analysis with Rank-Reduction): A method for analysis of stratified mark-recapture data from small populations, with application to estimating abundance of smolts from outmigrant trap data. National Marine Fisheries Service - Southwest Fisheries Science Center. Contribution 116. Administrative Report SC-00-02. 28 PP. DARR software – available at http://www.pfeg.noaa.gov/tib/index.htm

Bratovich, P. M. and D. W. Kelley. 1988. Investigations of salmon and steelhead in Lagunitas Creek, Marin County, California, Volume 1; migration, spawning, embryo incubation and emergence, juvenile rearing, emigration. Marin Municipal Water District, Corte Madera, California.

Brown, G.G. and B.J. Ketcham. 2002. Documentation of Coho Salmon (*Oncorhynchus kisutch)*in Pine Gulch Creek, Marin County, CA. Coho Salmon and Steelhead Trout Restoration Project. National Park Service, Point Reyes National Seashore, Point Reyes Station, California.

Brown, L.R., P.B. Moyle, and R.M. Yoshiyama. 1994. Historical decline and current status of coho salmon in California. North American Journal of Fish Management. 14:237-261.

California Cooperative Oceanic Fisheries Investigations (CalCOFI). 2006. The state of the California current, 2005-2006: Warm in the North, Cool in the South. State of the California Current. 47:30-74.

California Department of Fish and Game (CDFG). 2002. Status review of California coho salmon north of San Francisco. Sacramento, California.

California Department of Fish and Game (CDFG). 2003. Public Review draft Recovery Strategy for California Coho Salmon (*Onchorynchus kisutch*). Species Recovery Plan Report 2003-1. Sacramento, California.

California Department of Fish and Game (CDFG). 2004. Recovery strategy for California Coho Salmon (*Onchorynchus kisutch*). Sacramento, California.

Chapman, D.W. 1965. Net production of juvenile coho salmon in three Oregon streams. Transactions of the American Fish Society. 94:40-52.

Collins, Barry W. (editor). 2003. Interim restoration effectiveness and validation monitoring protocols, California Coastal Salmonid Restoration Monitoring and Evaluation Program. Report to the California Department of Fish and Game.

Cooprider, M.A. and R.G. Carson. 2006. San Francisco Bay Area Network Freshwater Quality Monitor Protocol Version 2.11. NPS/SFAN/NRR—2006/016. National Park Service, Fort Collins, Colorado.

Crone, R. A. and C. E. Bond. 1976. Life history of coho salmon in Sashin Creek, Southeast Alaska Fish Bulletin 74:897-923.

Del Real, S.C., M. Reichmuth, and B.J. Ketcham. 2007. Long-term coho salmon and steelhead trout monitoring program in Coastal Marin County – Summer 2006 preliminary monitoring progress report. National Park Service, Point Reyes National Seashore, Point Reyes Station, California.

Darroch, J.N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48: 241-260.

Dollof, C.A., D.G. Hankin, and G.H. Reeves. 1993. Basinwide estimation of habitat and fish populations in streams. Gen. Tech. Rept. SE-83. USDA Forest Service Southeastern Forest Experiment Station, Asheville, North Carolina.

Downie, S. and G. Petersen. undated. Spawning Inventory. California Department of Fish and Game. Unpublished instructions for conducting spawner surveys.

Efron, B., and R. Tibshirani. 1986. Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. Statistical Science 1:54-77.

Federal Register. 1996. Final Rule. Endangered and threatened species: Threatened status for Central California Coast coho salmon evolutionarily significant unit (ESU), October 31, 1996. 61 (212): 56138-56149.

Federal Register. 1997. Final Rule. Endangered and threatened species: Listing of several evolutionary significant units (ESU's) of west coast steelhead, August 18, 1997. 62(159): 43937-43954.

Federal Register. 1999. Final Rule and Correction. Endangered and threatened species: Designation of Critical Habitat; Central California Coast and Southern Oregon/Northern California Coasts Coho Salmon. May 5, 1999. 64(86): 24049-24062.

Federal Register. 2005. Final Rule. Endangered and Threatened Species: Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4(d) Protective Regulations for Threatened Salmonid ESUs, June 28, 2005. 70(123): 37160-37204.

Federal Register. 2006. Final Rule. Endangered and threatened species: Final listing determinations for 10 distinct population segments of west coast steelhead, January 5, 2006. 71(3): 834-862.

Flint, T. 1984. A comparison of stream indexing methods to estimate coho escapements in Harris Creek, 1980-1983. Canadian Technical Report on Fisheries and Aquatic Science 1326:149-159.

Flosi, G., Downie, S., Hopelain, J., Bird, M., Coey, R. and Collins, B. 1998. California salmonid stream habitat restoration manual. 1998. 3rd ed. California Department of Fish and Game, Sacramento, California. Available online (Dec. 2007): http://www.dfg.ca.gov/nafwb/pubs/manual3.pdf

Fong, D. In Press. SFAN Stream Flow Monitoring Protocol. NPS/SFAN/NRR—XXX. National Park Service, Fort Collins, Colorado.

Gallagher, S.P. 2000. Results of the 2000 Steelhead (*Oncorhynchus mykiss*) Fyke Trapping and Stream Resident Population Estimations and Predictions for the Noyo River, California with Comparison to Some Historic Information. California State Department of Fish and Game, Steelhead Research and Monitoring Program, Fort Bragg, California. Report FB-03.

Gallagher, S.P. and C.M. Gallagher. 2005. Discrimination of Chinook salmon, coho salmon, and steelhead redds and evaluation of the use of redd data for estimating escapement in several unregulated streams in northern California. North American Journal of Fish Management 25: 284-300.

Garza, C. and Gilbert-Horvath 2003. Report on the genetics of coho salmon (*Oncorhynchus kisutch*) held at the Warm Springs (Don Clausen) Hatchery for recovery efforts in the Russian River. NOAA Southwest Fisheries Science Center. Santa Cruz Laboratory, Santa Cruz, California.

Hassler, Thomas. J., 1987. Species Profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest) -- Coho. U.S. Fish and Wildlife Service Biol. Rep. 82 (11.70). U.S. Army Corps of Engineers, TR EL-82-4.

Irvine, J. R., R. C. Bocking, and K. K. English, and M. Labelle. 1992. Estimating coho salmon (*Oncorhynchus kisutch*) escapements by conducting visual surveys in areas selected using stratified random and stratified index sampling designs. Canadian Journal of Fish and Aquatic Science. 49: 1972-1981.

Johnston, N. T., J. R. Irvine, and C. J. Perrin. 1987. Instream indexing of coho salmon (*Oncorhynchus kisutch*) escapement in French Creek, British Columbia. Canadian Journal of Fish and Aquatic Science. No. 1573.

Jones & Stokes. 2007. Wetland and creek restoration at Big Lagoon, Muir Beach: Final Environmental Impact Statement/Environmental Impact Report. SCH# 2004042143 October. (J&S 05052.05.) Oakland, California.

Ketcham, B.J., Brown G.G., and Wolff, O.G. 2004. Olema Creek Watershed Summary Monitoring Report, Marin County, CA. 1997-2003. National Park Service, Point Reyes National Seashore, Point Reyes Station, California. PORE/NR/WR/04-02.

Ketcham, B., M. Reichmuth, D. Fong, and G. Brown. 2007. Draft Streamfish Monitoring Protocol V3.2. San Francisco Bay Area Network, Inventory and Monitoring Program. National Park Service.

Koski, K.V. 1966. The survival of coho salmon (*O. kisutch*) from egg deposition to emergence in three Oregon coastal streams. Master of Science Thesis. Oregon State University, Corvallis, Oregon.

Laufle, J.C., G.B. Pauley, and M.F. Shepard. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)--coho salmon. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.48). U.S. Army Corps of Engineers, TR EL-82-4.

MacFarlene, R.B., S. Hayes, and B. Wells. 2008. Coho and Chinook salmon decline in California during the spawning seasons of 2007/08. Unpublished report. prepared by Southwest Fisheries Science Center, Santa Cruz Laboratory, Santa Cruz, California.

Manning, D.J., and T.D. Roelofs. 1996. Coho Carrying Capacity and Limiting Habitats Analysis – 1996 Smolt Trapping Protocol. Report to National Park Service, Point Reyes National Seashore. Department of Fisheries, Humboldt State University.

Manning, D.J. 1999. Coho and Steelhead Restoration Project Annual Coho Salmon Spawner Survey Report: 1997-98. Coho and Steelhead Restoration Project. National Park Service, Point Reyes National Seashore, Point Reyes Station, California PORE-NR-WR-99/01.

Manning, D.J. 2001. Carrying capacity and limiting habitat analysis for coho salmon (*Oncorhynchus kisutch*) in streams of northwestern California. Humboldt State University: Masters Thesis.

MMWD. 2003. Lagunitas Creek coho salmon spawner survey report, 2002-2003. Marin Municipal Water District, Corte Madera, California.

MMWD 2005. Lagunitas Creek coho salmon spawner survey report, 2004-2005. Marin Municipal Water District, Corte Madera, California.

MMWD. 2006. Lagunitas Creek Salmon Spawner Survey Report 2005-2006. Marin Municipal Water District, Corte Madera, California.

MMWD. 2007. Lagunitas Creek Salmon Spawner Survey Report 2006-2007. Marin Municipal Water District, Corte Madera, California.

Miller, B.A., and S. Sandros. 2003 Residence time and seasonal movement of juvenile coho salmon in the ecotones and lower estuary of Winchester Creek, South Slough, Oregon. Transactins of the American Fisheries Society 132:546-559.

Moring, J. R., and R. L. Lantz. 1975. The Alsea watershed study: effects of logging on the aquatic resources of three headwater streams of the Alsea River, Oregon. Part I-Biological studies. Oregong Department of Fish and Wildlife, Fish Resource Report 9.

Moyle, P. B. 1976. Inland Fishes of California. Univ. California Press, Berkeley, California.

Moyle, P. B. 2002. Inland Fishes of California. Univ. California Press, Berkeley, California.

Murphy, B. R., and D.W. Willis. 1996. Fisheries Techniques. Second Edition. American Fisheries Society, Bethesda, Maryland.

National Marine Fisheries Service (NOAA Fisheries). 2001. Status review and update for coho salmon (*Onchorynchus kisutch*) from the central California coast and the California portion of the southern Oregon/northern California coasts Evolutionary Significant Units. Prepared by the Southwest Fisheries Science Center, Santa Cruz Laboratory, Santa Cruz, California. 40pp.

National Marine Fisheries Service (NOAA Fisheries). 2004. Biological Opinion for the National Park Service's livestock grazing program on NPS lands in Point Reyes National Seashore and Golden Gate National Recreation Area, April 5, 2004. Prepared by the Southwest Region Office, Long Beach, California

NPS. 2003. Draft stream aquatic resource monitoring protocol. San Francisco Area Network Inventory and Monitoring Program. National Park Service, Point Reyes National Seashore, Point Reyes Station, California

NPS. 2005. Coho Salmon Section 10 Permit Report - Permit #1046: January 1 – December 31, 2004. San Francisco Area Network - Golden Gate National Recreation Area, Point Reyes National Seashore, Muir Woods National Monument. National Park Service, Point Reyes National Seashore, Point Reyes Station, California PORE-NR- WR-05/05.

Nickelson, T.E., and P.W. Lawson. 1998. Population viability of coho salmon, *Oncorhynchus kisutch,* in Oregon coastal basins: application of a habitat-based life cycle model. Journal of Fish and Aquatic Science. 55:2383-2392.

Sandercock, F.K. 1991. Life history of coho salmon (Oncorhynchus kisutch). Pages 395-446. In: C. Groot and L. Margolis, eds. Pacific salmon life histories. UBC Press, Vancouver, British Columbia.

Shapovalov, L. and A.C. Taft. 1954. The life histories of the steelhead rainbow trout (Salmo gairdneri gairdneri) and silver salmon (Oncorhynchus kisutch) with specific reference to Waddell Creek, California, and recommendations regarding their management. California Department of Fish and Game Fish Bulletin 98.

Smith. J.J. 2001. Distribution and abundance of coho and steelhead in Redwood Creek in Fall 2001. National Park Service, Golden Gate National Recreation Area, San Francisco, California.

Solazzi M. F. 1984. Relationships between visual counts of coho salmon (*Oncorhynchus kisutch*) from spawning fish surveys and the actual number of fish present, p. 175-186. In P. E. K. Symons and M. Waldichuk (Eds.) Proceedings of the workshop on stream indexing for salmon escapement estimation. Canadian Technical Report of Fish and Aquatic Science 1326:258.

Thedinga, J. F., M. L. Murphy, S. W. Johnson, J. M. Lorenz, and K. V. Koski. 1994. Determination of salmonid smolt yield with rotary-screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management. 14:837-851.

Trihey and Associates, Inc. 1996 . Lagunitas Creek coho salmon spawner survey report fall and winter 1995-96. Marin Municipal Water District, Corte Madera, California.

Trihey and Associates, Inc. 1997 . Lagunitas Creek coho salmon spawner survey report fall and winter 1996-97. Marin Municipal Water District, Corte Madera, California.

Van den Berghe, E. F. and M. R. Gross. 1986. Length of breeding life of coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Zoology 64:1482-1486.

VanDeventer, J.S. and W.S. Platts. 1989. Microcomputer software system for generating population statistics from electrofishing data: users guide for Microfish 3.0. Gen. Tech. Rept. INT-254. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah.

Weitkamp, L. A., T. C. Wainwright, G. J. Bryant, G. B. Milner, D. J. Teel, R. G. Kope, and R. S. Waples. 1995. Status review of coho salmon from Washington, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-24. 258 p.

Wise, L. 1992. Memorandum - Lagunitas Creek coho spawner survey; Appendix K *In*. Habitat recommendations for Lagunitas Creek, Don Kelley and Associates and Entrix, Inc. for Marin Municipal Water District, Corte Madera, California.

Personal Communications

Duffy, Walt, PhD. Leader, California Cooperative Fishery Research Unit. Humboldt State University, Arcata, California.

.

Appendix A. SFAN Coho Monitoring Data Tables

Tables

Page

Table A1. Summary of habitat composition, extent of area sampled, and variation among reaches; Olema Creek, 2007.

Index Reach	Habitat Type	No. Units	Length		Surface Area	
			Sampled (m)	% of total	Sampled (m^2)	% of total
	Pool			not		
1	Riffle			Sampled		
	Flatwater					
	Total					
	Pool	2	72.20	100.00%	261.10	100.00%
2	Riffle	0	0.00	0.00%	0.00	0.00%
	Flatwater	0	0.00	0.00%	0.00	0.00%
	Total	2	72.20	100.00%	261.10	100.00%
	Pool	1	60.10	93.47%	274.46	96.39%
3	Riffle	1	4.20	6.53%	10.29	3.61%
	Flatwater	0	0.00	0.00%	0.00	0.00%
	Total	4	64.30	100.00%	284.75	100.00%
	Pool	3	39.40	70.74%	144.32	72.48%
4	Riffle	2	8.20	14.72%	17.95	9.01%
	Flatwater	1	8.10	14.54%	36.86	18.51%
	Total	6	55.70	100.00%	199.13	100.00%
	Pool	3	62.50	93.28%	322.25	95.53%
5	Riffle	1	4.50	6.72%	15.08	4.47%
	Flatwater	0	0.00	0.00%	0.00	0.00%
	Total	4	67.00	100.00%	337.33	100.00%
	Pool	3	58.00	79.78%	260.60	87.25%
6	Riffle	2	14.70	20.22%	38.09	12.75%
	Flatwater	0	0.00	0.00%	0.00	0.00%
	Total	5	72.70	100.00%	298.69	100.00%
	Pool	2	23.40	74.05%	85.82	74.67%
7	Riffle	0	0.00	0.00%	0.00	0.00%
	Flatwater	1	8.20	25.95%	29.11	25.33%
	Total	3	31.60	100.00%	114.93	100.00%
	Pool	2	45.50	94.20%	146.57	97.58%
8	Riffle	0	0.00	0.00%	0.00	0.00%
	Flatwater	1	2.80	5.80%	3.64	2.42%
	Total	3	48.30	100.00%	150.21	100.00%
	Pool	16	361.10	87.69%	1495.12	90.83%
Total	**Riffle**	**6**	**31.60**	**7.67%**	**81.41**	**4.95%**
	Flatwater	**3**	**19.10**	**4.64%**	**69.61**	**4.23%**
	Total	**25**	**411.80**	**100.00%**	**1646.14**	**100.00%**

Table A2. Summary of population and density estimates for each species by habitat unit on Olema Creek, Summer 2007; illustrates variation in distribution between habitat types.

Habitat	Species	Population Estimate		Density			
Type	(age)	No. Fish	95% CI	Fish/m	95% CI	Fish/m^2	95% CI
Pools (n=16)	CO	1,452	±116	4.01	±0.32	0.97	±0.08
	SH YOY	501	±84	1.39	±0.23	0.34	±0.06
	SH (1+)	69	±72	0.19	±0.20	0.05	±0.05
Riffles (n=6)	CO	3	±31	0.09	±0.98	0.04	±0.38
	SH YOY	229	±35	7.25	±1.10	2.81	±0.42
	SH (1+)	23	±51	0.73	±1.60	0.28	±0.62
Flatwater	CO	10	±13	0.52	±0.70	0.14	±0.19
(n=3)	SH YOY	30	±8	1.57	±0.41	0.43	±0.11
	SH (1+)	0		0		0	
All Habitat	**CO**			**3.56**	**±0.39**	**0.89**	**±0.10**
Types:	**SH (0+)**			**1.84**	**±0.31**	**0.46**	**±0.08**
Average	**SH (1+)**			**0.22**	**±0.37**	**0.06**	**±0.09**
Density							

Table A3. Summary of population and density estimates for each species by reach on Olema Creek, Summer 2007; illustrates variation between reaches and provides a general idea of distribution within watershed.

Index Reach	Species (age)	Population Estimate No. Fish	95% CI	Fish/m	95% CI	Density Fish/m^2	95% CI
	CO						
1	SH YOY	not surveyed					
	SH (1+)						
	CO	123	±3	1.70	±0.04	0.47	±0.01
2	SH YOY	113	±8	1.57	±0.12	0.43	±0.03
	SH (1+)	9	±11.7	0.12	±0.16	0.03	±0.04
	CO	210	±39	3.27	±0.60	0.74	±0.14
3	SH YOY	160	±30	2.49	±0.47	0.56	±0.11
	SH (1+)	22	±11	0.34	±0.17	0.08	±0.04
	CO	241	±35	4.33	±0.64	1.21	±0.18
4	SH YOY	268	±49	1.81	±0.21	0.36	±0.04
	SH (1+)	16	±54	0.29	±0.97	0.08	±0.27
	CO	350	±47	5.22	±0.70	1.04	±0.14
5	SH YOY	121	±14	1.81	±0.21	0.36	±0.04
	SH (1+)	19	±14	0.26	±0.18	0.05	±0.04
	CO	218	±14	3.00	±0.19	0.73	±0.05
6	SH YOY	51	±12	0.70	±0.16	0.17	±0.04
	SH (1+)	15	±25	0.21	±0.35	0.05	±0.09
	CO	161	±9	5.09	±0.30	1.40	±0.08
7	SH YOY	10	±5	0.32	±0.16	0.09	±0.04
	SH (1+)	3	±23	0.13	±0.22	0.04	±0.06
	CO	162	±13	3.35	±0.2	1.08	±0.09
8	SH YOY	37	±9	0.77	±0.18	0.25	±0.06
	SH (1+)	8	±14	0.13	±0.22	0.04	±0.06
Average Densities for All Reaches	**CO**			**3.56**	**±0.39**	**0.89**	**±0.10**
	SH (0+)			**1.84**	**±0.31**	**0.46**	**±0.08**
	SH (1+)			**0.22**	**±0.37**	**0.06**	**±0.09**

Table A4. Summary of habitat composition for Pine Gulch Creek, 2007; shows extent of area sampled and variation between reaches.

Index Reach	Habitat Type	# of Units	Length		Surface Area	
			Sampled (m)	% of total	Sampled (m^2)	% of total
	Pool	1	10.3	100.00%	36.56	100.00%
1a	Riffle	0	0	0.00%	0	0.00%
	Flatwater	0	0	0.00%	0	0.00%
	Total	1	10.3	100.00%	36.56	100.00%
	Pool	2	33.7	44.28%	42.40	23.66%
1b	Riffle	0	0	0.00%	0	0.00%
	Flatwater	2	42.4	55.72%	136.82	76.34%
	Total	4	76.1	100.00%	179.22	100.00%
	Pool	3	59.8	92.00%	203.08	94.26%
1c	Riffle	2	5.2	8.00%	12.36	5.74%
	Flatwater	0	0	0.00%	0	0.00%
	Total	5	65.0	100.00%	215.44	100.00%
	Pool	2	30.3	56.53%	129.72	61.60%
2	Riffle	2	13.7	25.56%	45.02	21.38%
	Flatwater	1	9.6	17.91%	35.84	17.02%
	Total	5	53.6	100.00%	210.58	100.00%
	Pool	2	43.8	53.28%	139.27	57.67%
3	Riffle	2	30.4	36.98%	77.81	32.22%
	Flatwater	1	8.0	9.73%	24.40	10.10%
	Total	5	82.2	100.00%	241.48	100.00%
	Pool					
4	Riffle			not sampled		
	Flatwater					
	Total					
	Pool	3	41.3	69.65%	123.13	69.78%
5	Riffle	2	18.0	30.35%	53.33	30.22%
	Flatwater	0	0	0.00%	0	0.00%
	Total	5	59.3	100.00%	176.46	100.00%
	Pool	3	32.9	61.27%	80.24	58.60%
6	Riffle	2	20.8	38.73%	56.69	41.40%
	Flatwater	0	0	0.00%	0	0.00%
	Total	5	53.7	100.00%	136.93	100.00%
	Pool	16	252.1	62.99%	754.40	63.04%
Total for all reaches	**Riffle**	**10**	**88.1**	**22.02%**	**245.21**	**20.49%**
	Flatwater	**4**	**60.0**	**14.99%**	**197.06**	**16.47%**
	Total	**30**	**400.2**	**100.00%**	**1,196.67**	**100.00%**

Table A5. Summary of population and density estimates for each species by reach on Pine Gulch Creek, Summer 2007; illustrates variation between reaches and provides a general idea of distribution within watershed.

Index Reach	Species (age)	Population Estimate # of Fish	95% CI	Density Fish/m	95% CI	Fish/m^2	95% CI
	CO	0		0		0	
1a	SH YOY	3	±3	0.29	±0.30	0.08	±0.08
	SH (1+)	2	±9	0.20	±0.90	0.05	±0.25
	CO	0		0		0	
1b	SH YOY	39	±6	0.51	±0.07	0.15	±0.02
	SH (1+)	21	±16	0.28	±0.08	0.10	±0.06
	CO	0		0		0	
1c	SH YOY	62	±24	0.95	±0.38	0.29	±0.11
	SH (1+)	29	±23	0.45	±0.36	0.13	±0.11
	CO	0		0		0	
2	SH YOY	148	±15	2.76	±0.27	0.70	±0.07
	SH (1+)	23	±32	0.43	±0.60	0.11	±0.15
	CO	0		0		0	0
3	SH YOY	167	±82	2.03	±0.45	0.69	±0.15
	SH (1+)	13	±40	0.16	±0.48	0.05	±0.16
	CO						
4	SH YOY	not surveyed					
	SH (1+)						
	CO	0		0		0	
5	SH YOY	56	±21	0.94	±0.35	0.32	±0.12
	SH (1+)	23	±24	0.39	±0.41	0.13	±0.14
	CO	0		0		0	
6	SH YOY	52	±16	0.97	±0.31	0.38	±0.12
	SH (1+)	14	±31	0.26	±0.58	0.10	±0.23
All Index Reaches: Average Densities	**CO**			**0.00**		**0.00**	
	SH (0+)			**1.32**	**±0.30**	**0.42**	**±0.10**
	SH (1+)			**0.32**	**±0.43**	**0.10**	**±0.14**

Table A6. Summary of population and density estimates for each species by habitat unit on Pine Gulch Creek, Summer 2007; illustrates variation in distribution between habitat types.

Habitat	Species	Population Estimate		Density			
Type	(age)	# of Fish	95% CI	Fish/m	95% CI	Fish/m^2	95% CI
Pools (n=16)	CO	0		0		0	
	SH YOY	404	±58	1.60	±0.23	0.49	±0.07
	SH (1+)	113	±47	0.45	±0.19	0.14	±0.06
Riffles (n=10)	CO	0		0		0	
	SH YOY	79	±46	0.90	±0.53	0.32	±0.19
	SH (1+)	4	±96	0.05	±0.02	0.02	±0.39
Flatwater	CO	0		0		0	
(n=4)	SH YOY	44	±17	0.73	±0.22	0.22	±0.08
	SH (1+)	8	±30	0.13	±0.10	0.04	±0.15
All Types:	**CO**			**0.00**		**0.00**	
Average	**SH (0+)**			**1.32**	**±0.30**	**0.42**	**±0.10**
Density	**SH (1+)**			**0.32**	**±0.43**	**0.10**	**±0.14**

Table A7. Summary of habitat composition, Redwood Creek 2007; shows extent of area sampled and variation between reaches.

Index Reach	Habitat Type	No. Units	Length Sampled (m)	Length % of total	Surface area Sampled (m^2)	Surface area % of total
	Pool	3	39.9	36.24%	145.33	40.42%
1	Riffle	3	46.2	41.96%	144.31	40.13%
	Flatwater	2	24.0	21.80%	69.94	19.45%
	Total	8	110.1	100.00%	359.58	100.00%
	Pool	3	42.1	39.98%	209.91	52.52%
2	Riffle	2	25.1	23.84%	65.74	16.45%
	Flatwater	2	38.1	36.18%	124.06	31.04%
	Total	7	105.3	100.00%	399.71	100.00%
	Pool	4	59.2	79.36%	224.15	86.59%
3	Riffle	2	15.4	20.64%	34.72	13.41%
	Flatwater	0	0.0	0.00%	0.00	0.00%
	Total	6	74.6	100.00%	258.87	100.00%
	Pool	4	57.9	69.93%	211.18	81.67%
4	Riffle	2	9.7	11.71%	11.84	4.58%
	Flatwater	2	15.2	0.00%	35.55	13.75%
	Total	8	82.8	100.00%	258.57	100.00%
	Pool	3	74.2	68.90%	323.79	72.27%
5	Riffle	1	4.2	3.90%	5.25	1.17%
	Flatwater	1	29.3	0.00%	118.99	26.56%
	Total	5	107.7	100.00%	448.03	100.00%
	Pool	3	78.1	92.10%	273.27	95.66%
6	Riffle	1	6.7	7.90%	12.39	4.34%
	Flatwater	0	0.0	0.00%	0.00	0.00%
	Total	4	84.8	100.00%	285.66	100.00%
	Pool	2	32.4	40.96%	84.51	46.91%
7	Riffle	2	3.8	4.80%	4.05	4.42%
	Flatwater	3	42.9	54.24%	91.61	50.85%
	Total	7	79.1	100.00%	180.17	102.17%
	Pool	18	383.8	59.56%	1472.14	67.20%
Total	**Riffle**	**13**	**111.1**	**17.24%**	**278.30**	**12.70%**
	Flatwater	**10**	**149.5**	**23.20%**	**440.15**	**20.09%**
	Total	**41**	**644.4**	**100.00%**	**2,190.59**	**100.00%**

Table A8. Summary of population and density estimates for each species by habitat unit on Redwood Creek, Summer 2007; illustrates variation in distribution between habitat types.

Habitat	Species	Population Estimate		Density			
Type	(age)	# of Fish	95% CI	Fish/m	95% CI	Fish/m^2	95% CI
Pools (n=16)	CO	761	±51	1.98	±0.13	0.52	±0.03
	SH YOY	1,200	±95	3.13	±0.25	0.82	±0.06
	SH (1+)	90	±138	0.23	±0.36	0.06	±0.09
Riffles (n=6)	CO	2	±109	0.02	±0.98	0.01	±0.39
	SH YOY	58	±60	0.52	±0.54	0.21	±0.22
	SH (1+)	1	±120	0.01	±1.08	0.00	±0.43
Flatwater (n=3)	CO	12	±69	0.08	±0.46	0.03	±0.16
	SH YOY	255	±65	1.71	±0.43	0.58	±0.15
	SH (1+)	6	±95	0.04	±0.63	0.01	±0.21
All Types:	**CO**			**1.20**	**±0.36**	**0.35**	**±0.10**
Average Density	**SH (0+)**			**2.35**	**±0.34**	**0.69**	**±0.10**
	SH (1+)			**0.15**	**±0.55**	**0.04**	**±0.16**

Table A9. Summary of population and density estimates for each species by reach on Redwood Creek, Summer 2007; illustrates variation between reaches and provides a general idea of distribution within watershed.

Index Reach	Species (age)	Population Estimate # of Fish	95% CI	Density Fish/m	95% CI	Fish/m^2	95% CI
	CO	54	±38	0.49	±0.35	0.15	±0.11
1	SH YOY	98	±83	1.57	±0.15	0.41	±0.04
	SH (1+)	8	±65	0.07	±0.59	0.02	±0.18
	CO	138	±35	1.31	±0.33	0.35	±0.09
2	SH YOY	165	±15	1.57	±0.15	0.41	±0.04
	SH (1+)	43	±47	0.41	±0.44	0.11	±0.12
	CO	215	±18	2.88	±0.25	0.83	±0.07
3	SH YOY	305	±8	4.09	±0.10	1.18	±0.03
	SH (1+)	10	±44	0.13	±0.59	0.04	±0.17
	CO	125	±56	1.51	±0.68	0.48	±0.22
4	SH YOY	179	±43	2.16	±0.52	0.69	±0.16
	SH (1+)	11	±63	0.13	±0.76	0.04	±0.04
	CO	146	±22	1.36	±0.21	0.33	±0.05
5	SH YOY	215	±18	2.00	±0.17	0.48	±0.04
	SH (1+)	7	±38	0.06	±0.35	0.02	±0.08
	CO	89	±15	1.05	±0.18	0.31	±0.05
6	SH YOY	396	±10	4.67	±0.12	1.39	±0.04
	SH (1+)	11	±34	0.13	±0.40	0.04	±0.12
	CO	8	±52	0.10	±0.65	0.04	±0.29
7	SH YOY	155	±42	1.96	±0.53	0.86	±0.23
	SH (1+)	7	±61	0.09	±0.78	0.04	±0.34
All Reaches:	**CO**			**1.20**	**±0.36**	**0.35**	**±0.10**
Average	**SH (0+)**			**2.35**	**±0.34**	**0.69**	**±0.10**
Densities	**SH (1+)**			**0.15**	**±0.55**	**0.04**	**±0.16**

Table A10. Coho spawner survey redd density history for mainstem Lagunitas Creek, San Geronimo Creek, Devil's Gulch, Olema Creek, John West Fork, Redwood Creek, and Pine Gulch including total redds (TR), survey length (SL) and redd density (RD).

Years	Lagunitas Creek			San Geronimo Creek			Devil's Gulch			Olema Creek			John West Fork			Redwood Creek			Pine Gulch		
	TR	SL	RD	TR	SL	RD	TR	SL	RD	TR	SL	RD	TR	SL	RD	TR	SL	RD	TR	SL	RD
1997-1998	80	10.7	7.5	107	7.0	15.3	52	3.2	16.3	126	13.4	9.4	7	2.0	3.5	74	7.4	10.0	N/A	N/A	N/A
1998-1999	92	10.7	8.6	46	7.0	6.6	32	3.2	10.0	42	11.6	3.6	1	2.0	0.5	55	7.4	7.4	N/A	N/A	N/A
1999-2000	139	10.7	13.0	58	7.0	8.3	3	3.2	0.9	10	7.2	1.4	7	2.0	3.5	7	7.4	0.9	N/A	N/A	N/A
2000-2001	119	12.8	9.3	56	7.0	8.0	11	3.2	3.4	86	11.6	7.4	48	2.0	24	35	7.4	4.7	0	9.5	0
2001-2002	79	12.8	6.2	102	7.0	14.5	59	3.7	16.1	58	11.6	5.0	31	2.0	15.5	29	7.4	3.9	2	9.5	0.2
2002-2003	71	12.8	5.5	39	7.0	5.6	24	3.7	6.6	5	11.6	0.4	12	2.0	6	5	7.4	0.7	1	9.5	0.1
2003-2004	124	12.8	9.7	139	7.0	19.8	48	3.7	13.1	88	11.6	7.6	21	2.0	10.5	43	7.4	5.8	0	9.5	0
2004-2005	120	12.8	9.4	138	7.0	19.7	112	3.7	30.6	92	11.6	7.9	45	2.0	22.5	74	7.4	10.0	3	9.5	0.3
2005-2006	53	12.8	4.1	48	7.0	6.9	33	3.7	8.9	2	11.6	0.2	4	2.0	2	12	7.4	1.6	1	9.5	0.1
2006-2007	128	12.8	10.0	117	7.0	16.7	55	3.7	14.9	66	11.6	5.7	29	2.0	14.5	21	7.4	2.8	0	9.5	0

Appendix B. GSS Survey Results

Figures

Page

Tables

Page

B.1 John West Fork (Olema Creek)

John West Fork is the largest of the Olema Creek tributaries surveyed, and the largest contributer of coho and steelhead production of any of the tributaries. The 2007 summer habitat survey of John West Fork was initiated at the confluence with the Olema mainstem and ended at monument tag 19. The measured GSS survey length was 1.3 km. In previous years, this length ranged from 1.8 km to 3.0 km.

B.1.1 Habitat Survey

A total of 144 habitat units were delineated within the GSS survey area with 46 pool units representing 35.5% of the total length. Nine pools were selected and sampled representing a 20% subsample. Intermittent conditions were observed approximately 502m upstream from the confluence with Olema Creek. Dry sections of streambed accounted for 336 meters of the total length surveyed. Figure B1 shows a comparison between available habitat in 2007 and the historical available habitat for previous years.

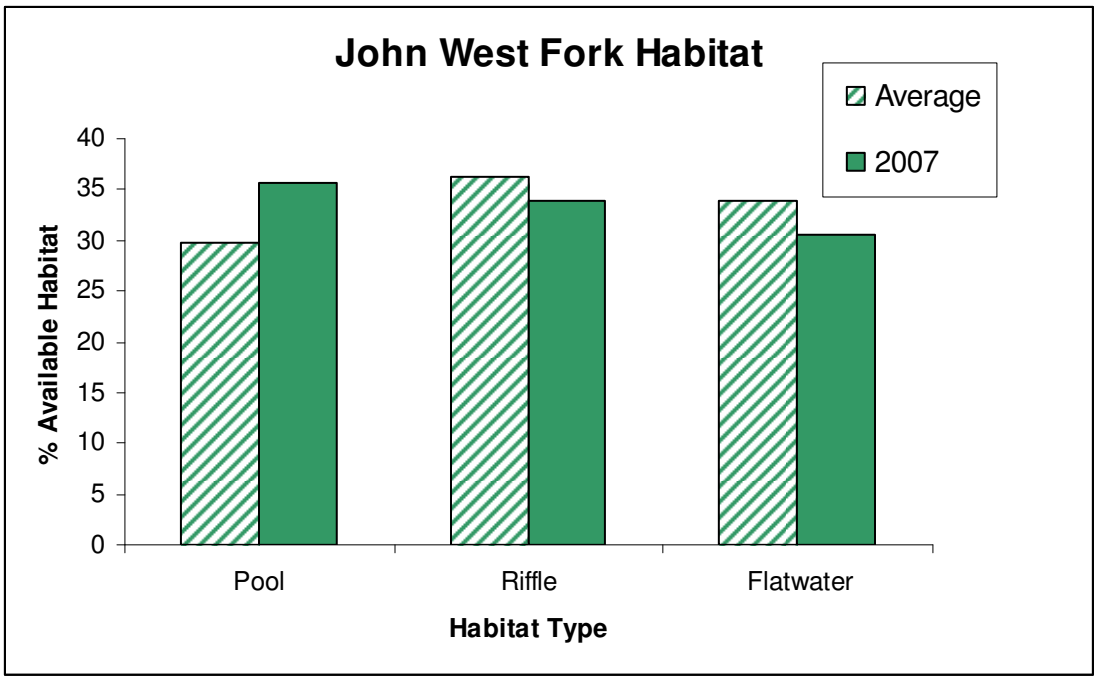


Figure B1. Composition of available habitat on John West Fork. Historical averages offered for comparison (2005-2006).

Summer fish measurement information: As part of the summer monitoring program, a subsample of fish are weighed and measured within each sampled habitat unit. Histograms are presented for coho (Figure B2) and steelhead (Figure B4), showing comparisons between 2007 and historial averages. Weight-length relationships are shown for coho (Figures B3) and steelhead (Figure B5), showing comparisons between 2007 and historical averages.

Within the John West Fork sample, 134 coho salmon (39% of the total catch) and 122 steelhead trout (40% of the total catch) were weighed and measured. The size range for young of year coho

was observed to be 44 mm to 86 mm, while the size range for steelhead trout was 41 mm to 236 mm.

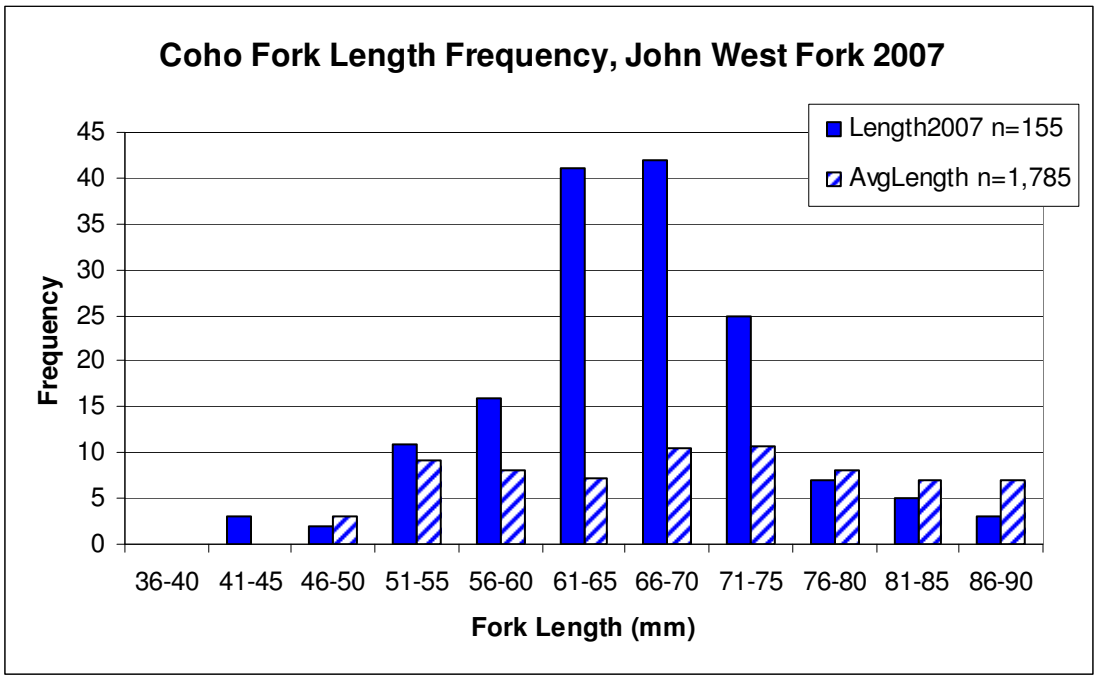


Figure B2. Coho histogram for fish measured in John West Fork, 2007. Historical averages are added for comparison (2005-2006). Fork length is represented in 5 millimeter bins.

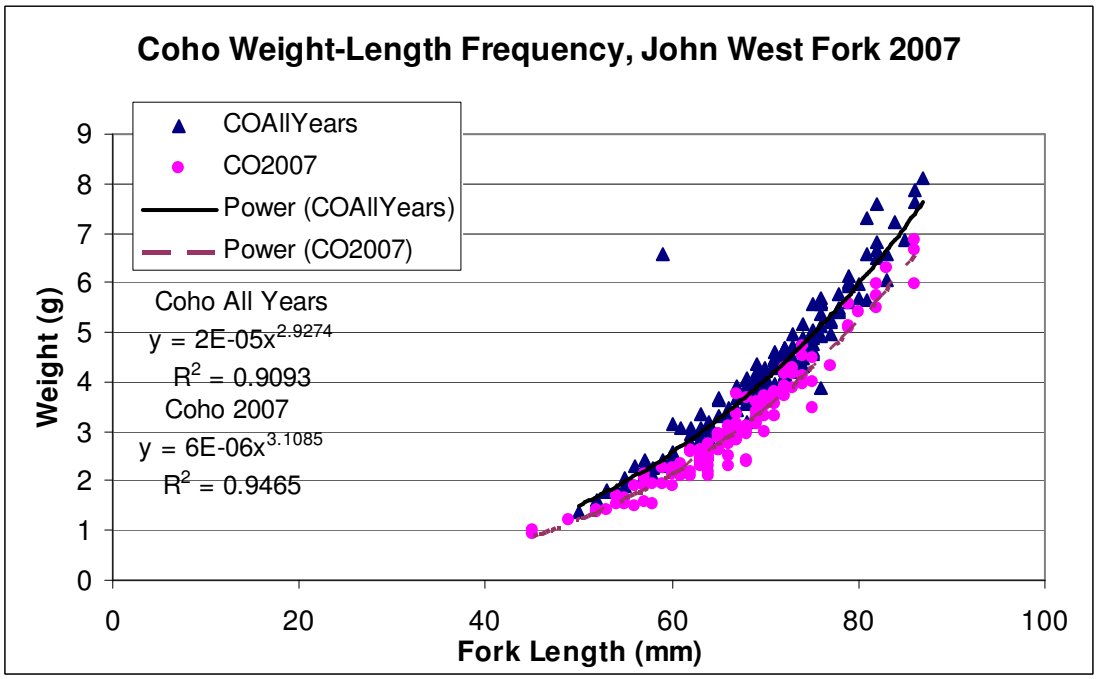


Figure B3. Coho weight-length relationship for fish measured in John West Fork, 2007. Also shown is the weight-length relationship for coho measured in previous years (2005-2006).

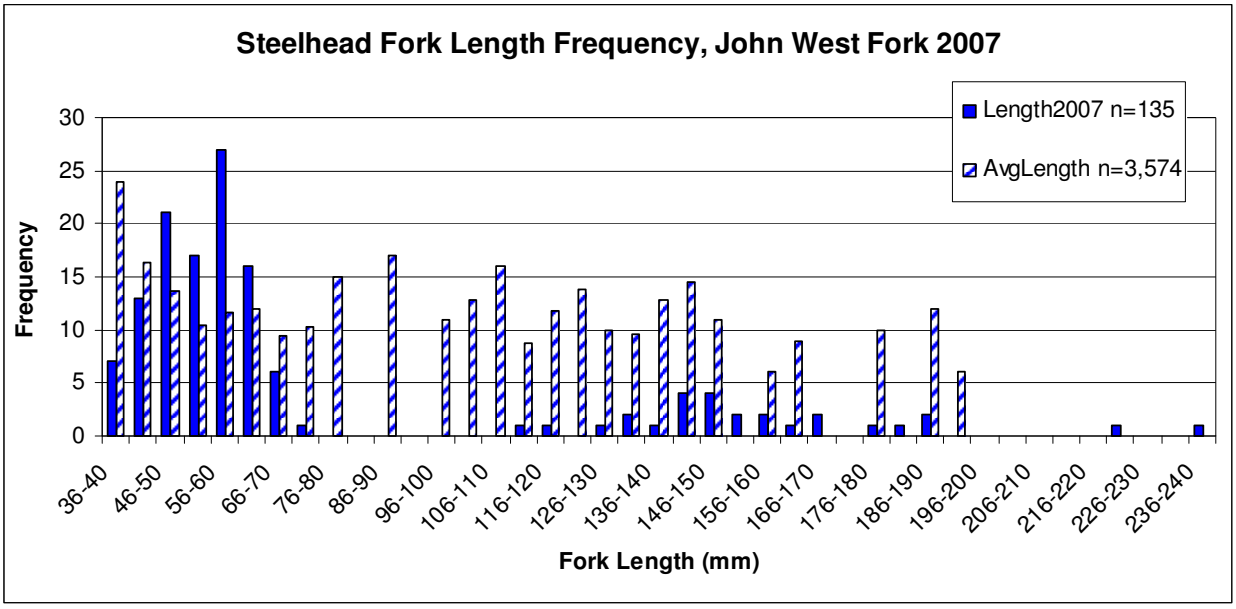


Figure B4. Steelhead histogram for fish measured in John West Fork, 2007. Historical averages are added for comparison (2005-2006). Fork length is represented in 5 millimeter bins

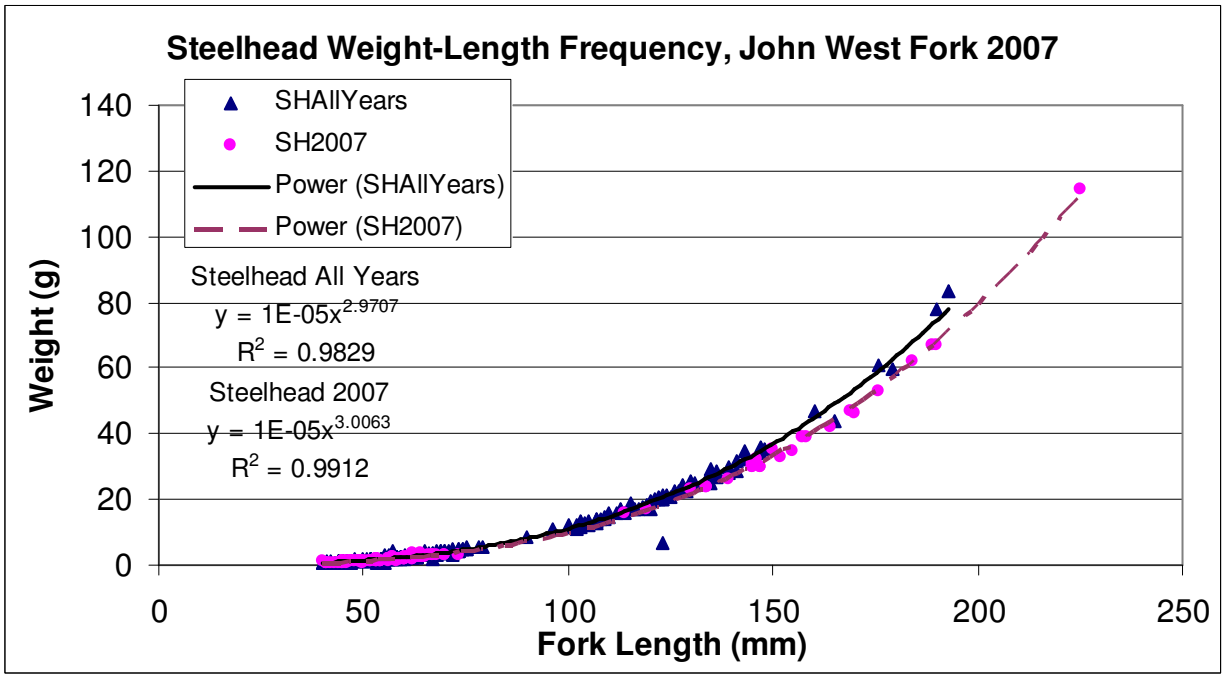


Figure B5. Steelhead weight-length relationship for fish measured in John West Fork,, 2007. Also shown is the weight-length relationship for steelhead measured in previous years (2005-2006).

Table B1 shows the coho length, weight, and K-factor for John West Fork measured between 2005 and 2007. Tables B2 and B3 show the comparisons between steelhead young of the year (YOY) and steelhead 1+ length, weight, and K-factors for John West Fork measured between 2005 and 2007.

Table B1. Mean length, weight, K-factor, and standard deviation (SD) calculated for coho measured and weighed in John West Fork, 2005-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2007	134	66.27	7.74	3.05	1.17	1.00	0.09
2006	59	71.17	3.52	4.24	0.67	1.17	0.07
2005	125	68.98	8.58	4.08	1.53	1.20	0.20

Table B2. Mean length, weight, K-factor, and standard deviation (SD) calculated for steelhead YOY measured and weighed in John West Fork, 2005-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2007	96	54.67	7.66	1.71	0.73	0.99	0.14
2006	163	56.82	11.80	2.44	2.82	1.15	0.17
2005	58	61.79	7.20	2.76	0.98	1.13	0.13

Table B3. Mean length, weight, K-factor, and standard deviation (SD) calculated for steelhead 1+ measured and weighed in John West Fork, 2005-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2007	26	154.96	24.05	39.29	20.57	0.99	0.03
2006	63	122.86	21.16	22.22	14.04	1.10	0.11
2005	7	140.29	22.16	32.20	15.39	1.10	0.05

B.1.2 Electrofishing Counts

Electrofishing surveys were conducted on 20% of the delineated pools with coho being observed in 100% of the total pools sampled. A total of 345 coho were counted in the nine e-fished pools giving an average of 43.1 coho per pool. Steelhead were observed in 88% of the total pools sampled. A total of 305 steelhead (including YOY and 1+) were counted in the e-fished pools giving an average of 38.1 steelhead per pool (Table B4).

Table B4. Summary of total catch for GSS survey on John West Fork, 2006-2007.

Year	Total Length Surveyed (km)	Total Habitat Units	Number of Pools					Raw Totals		
			Total	E-Fished	w/ coho	w/ SH YOY	w/ SH 1+	CO	SH YOY	SH 1+
2007	1.3	144	46	8	8	7	5	345	278	27
2006	1.8	151	43	10	8	10	10	75	371	78

B.1.3 Population Estimates

Estimates for population size and variance, in addition to, a 95% confidence interval were derived from the 2007 John West Fork equiprobable GSS survey. Results are shown in Table B5. In 2007, John West Fork contributed an estimated 2,064 coho to the Olema Creek Watershed.

Table B5. John West Fork population estimates and confidence intervals (CI), 2007.

Year	Species	Population Estimate	Variance	95% CI
2007	CO	2,064	84,544	±582
	SH YOY	1,748	187,591	±866
	SH 1+	155	3,061	±111

B.2 Giacomini Creek (Olema Creek)

Giacomini Creek is a second Olema Creek tributary surveyed during the summer basinwide surveys and a contributor to the greater Olema Creek watershed. It is generally the smallest of the tributaries surveyed, and contributes the lowest numbers of coho to the Olema Creek Watershed.

The 2007 summer habitat survey of Giacomini Creek was initiated at the confluence with the Olema mainstem and ended at monument tag 2 where the creek went from intermittent to dry. The measured GSS survey length was 0.18 km. In previous years, that length has ranged from 0.3 km to 1.1 km.

B.2.1 Habitat Survey

In 2007, a total of 19 habitat units were delineated within the GSS survey area with 2 pool units representing 11% of the total units. The pool created by the culvert outfall was sampled while the only other remaining pool had decreased in depth by the time of the e-fishing survey below pool thresholds and was not sampled. Intermittent conditions were observed throughout the survey area. Dry sections of streambed accounted for 174 meters of the total length surveyed. Figure B6 is shows the 2007 survey results compared to the historic averages of percentage of available habitat.

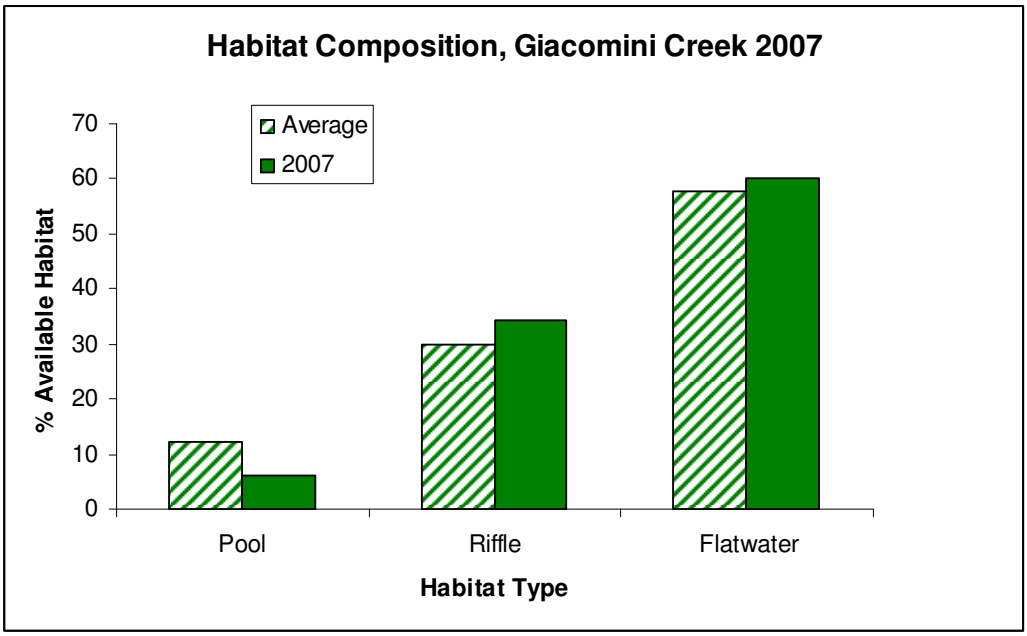


Figure B6. Comparison of historic (2005-2006) average percent of available habitat and 2007 survey.

Summer fish measurement information: As part of the summer monitoring program, a subsample of fish are weighed and measured within each sampled habitat unit. Histograms are presented for coho (Figure B7) and steelhead (Figure B9). Weight-length relationships are shown for coho (Figures B8) and steelhead (Figure B10). Historic data are offered for comparison on the steelhead figures. Only one coho was found on Giacomini in 2006.

Within the Giacomini Creek sample, 18 coho salmon (32% of the total catch) and 13 steelhead trout (93% of the total catch) were weighed and measured. The size range for young-of-year coho was observed to be 35 mm to 92 mm, while the size range for steelhead trout was 45 mm to 179 mm.

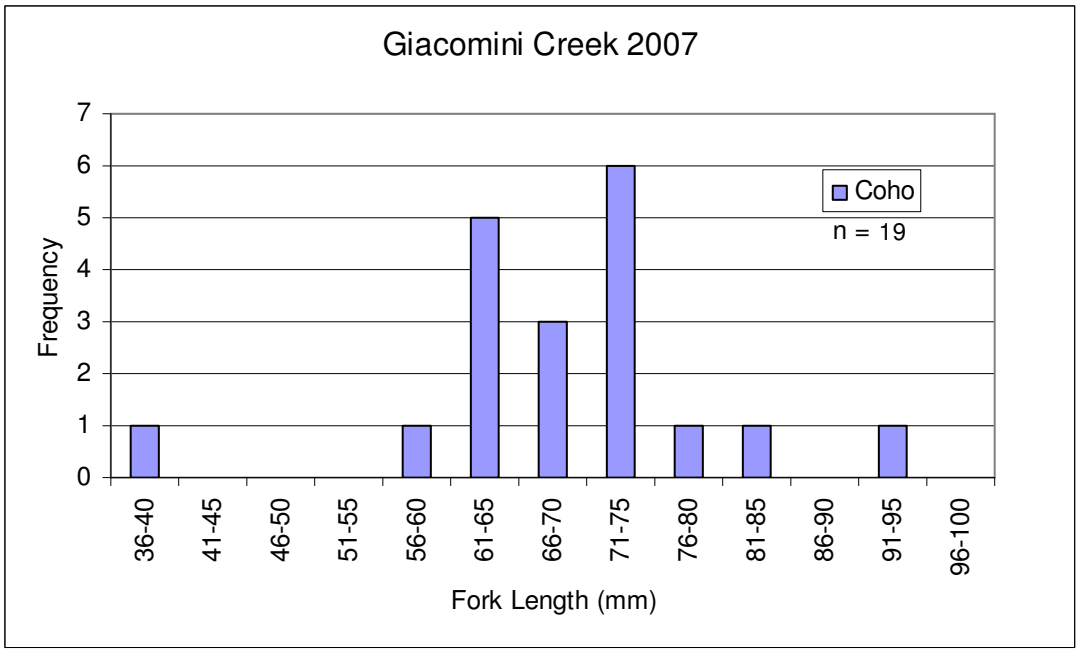


Figure B7. Coho histogram for fish measured in Giacomini Creek, 2007. Fork length is represented in 5 millimeter bins.

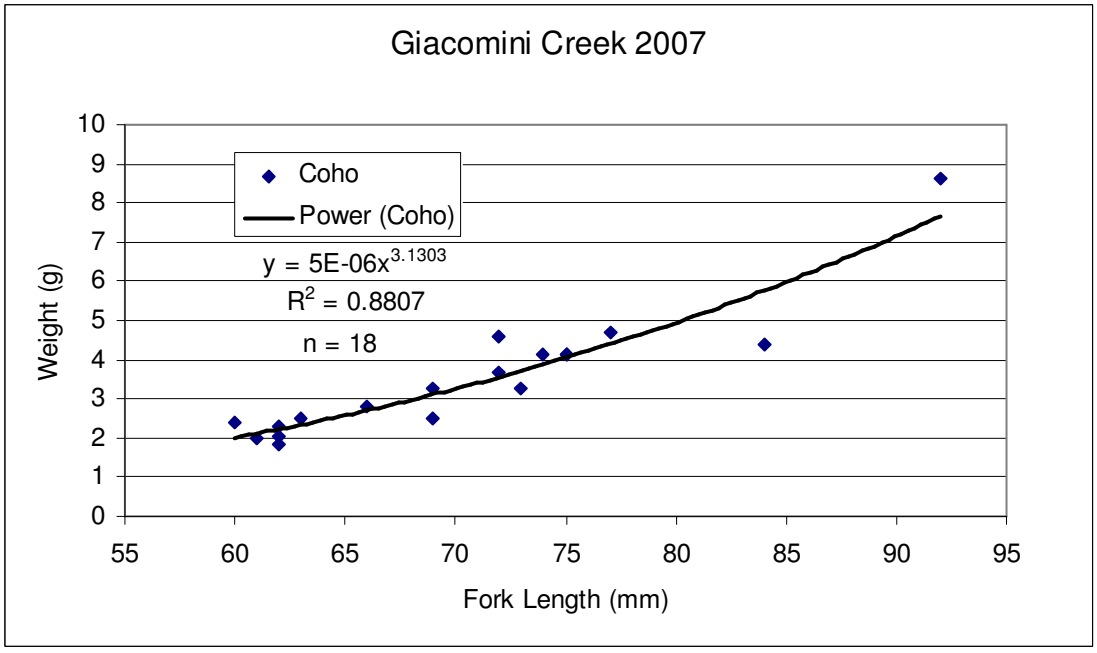


Figure B8. Coho weight-length relationship for fish measured in Giacomini Creek, 2007.

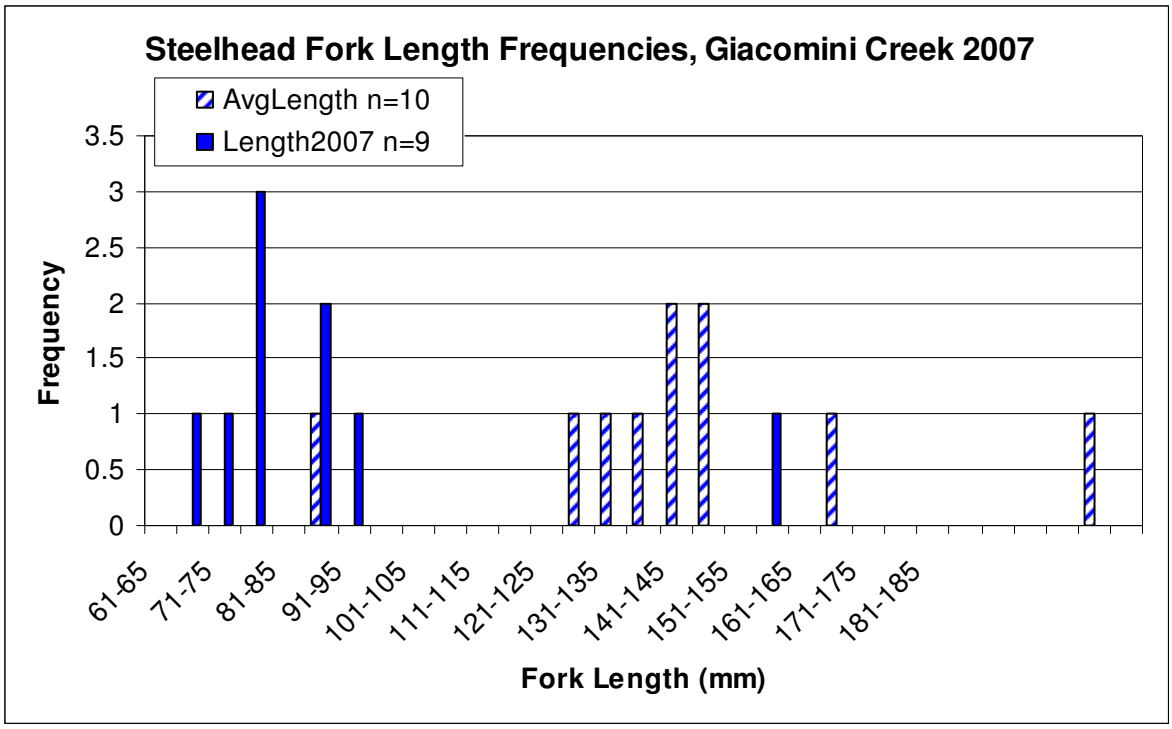


Figure B9. Steelhead histogram for fish measured in Giacomini Creek, 2007. Historic averages are offered for comparison (2006). Fork length is represented in 5 millimeter bins.

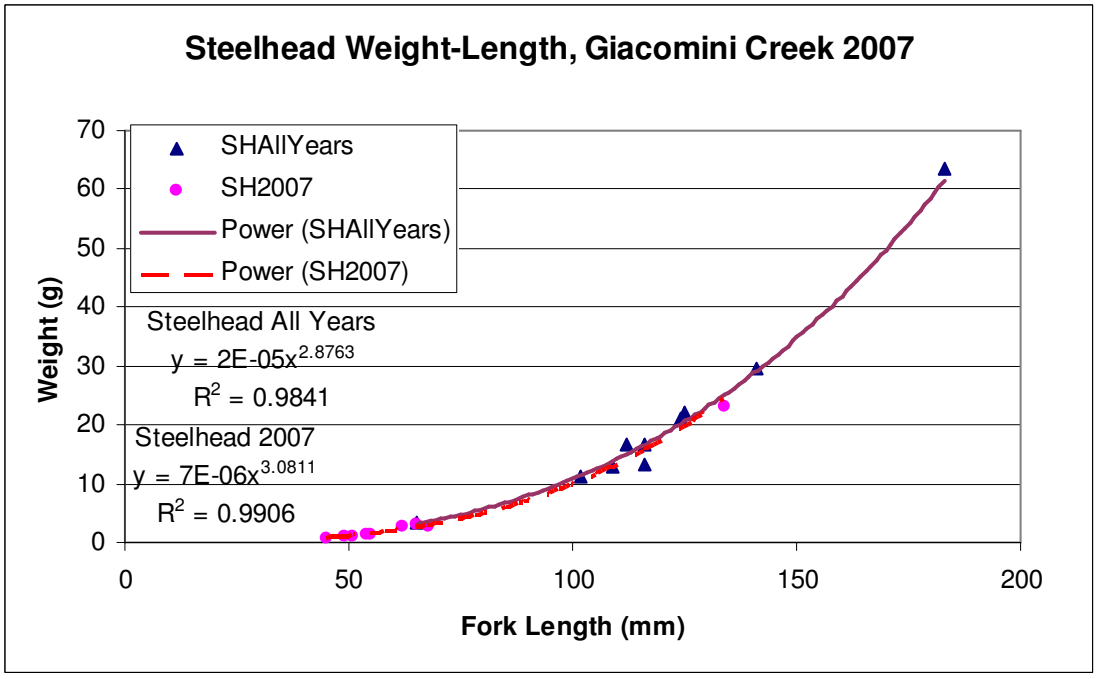


Figure B10. Steelhead weight-length relationship for fish measured in Giacomini Creek, 2007. Historic data offered for comparison (2006).

Table B6 shows the coho length, weight, and K-factor for Giacomini Creek. Tables B7 and B8 show the comparisons between steelhead young-of-year (YOY) and steelhead 1+ length, weight, and K-factors for Giacomini Creek during sample years 2006-2007.

Table B6. Mean length, weight, K-factor, and standard deviation (SD) calculated for coho measured and weighed in Giacomini Creek, 2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2007	18	70.44	8.57	3.52	1.59	0.96	0.13
2006	1	88.00	N/A	7.84	N/A	1.10	N/A

Table B7. Mean length, weight, K-factor, and standard deviation (SD) calculated for steelhead YOY measured and weighed in Giacomini Creek, 2006-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2007	8		5.34	1.60	0.38	1.03	0.13
2006	1	65	N/A	3.3	N/A	1.20	N/A

Table B8. Mean length, weight, K-factor, and standard deviation (SD) calculated for steelhead 1+ measured and weighed in Giacomini Creek, 2006-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2007	5	154.60	20.28	38.67	14.55	1.00	0.05
2006	9	125.33	24.33	22.99	16.29	1.05	0.10

B.2.2. Electrofishing Counts

Electrofishing surveys were conducted on 50% of the delineated pools with coho being observed in the one sampled pool. A total of 56 coho was counted in the one e-fished pool. Steelhead were observed in 50% of the total pools sampled. A total of 14 steelhead (both YOY and 1+) were counted in the e-fished pool (Table B9).

Table B9. Summary of total catch for GSS survey on Giacomini Creek, 2006-2007.

Year	Total Length Surveyed (km)	Total Habitat Units	Number of Pools					Raw Totals		
			Total	E-Fished	w/coho	w/SH YOY	w/SH 1+	CO	SH YOY	SH 1+
2007	0.18	19	2	1	1	1	1	56	9	5
2006	0.3	25	3	2	1	1	1	1	1	9

Population Estimate: No population estimates for Giacomini Creek were derived from the one e-fished pool.

B.3 Quarry Gulch (Olema Creek)

Quarry Gulch is the third Olema Creek tributary surveyed during the summer basinwide surveys. While it generally produces greater coho numbers that Giacomini Creek, its numbers are lower than John West Fork coho numbers.

The 2007 summer habitat survey of Quarry Gulch was initiated at the confluence with the Olema mainstem and ended below the State Route 1 culvert. The measured GSS survey length was 0.67 km. In previous years, this survey length has ranged from 0.64 km to 0.84 km.

B.3.1 Habitat Survey

In 2007, a total of 100 habitat units were delineated within the GSS survey area with 23 pool units representing 23% of the total units. Four pools were selected and sampled representing a 17% subsample. Figure B11 shows a comparison between historical average available habitat and the results from the 2007 survey.

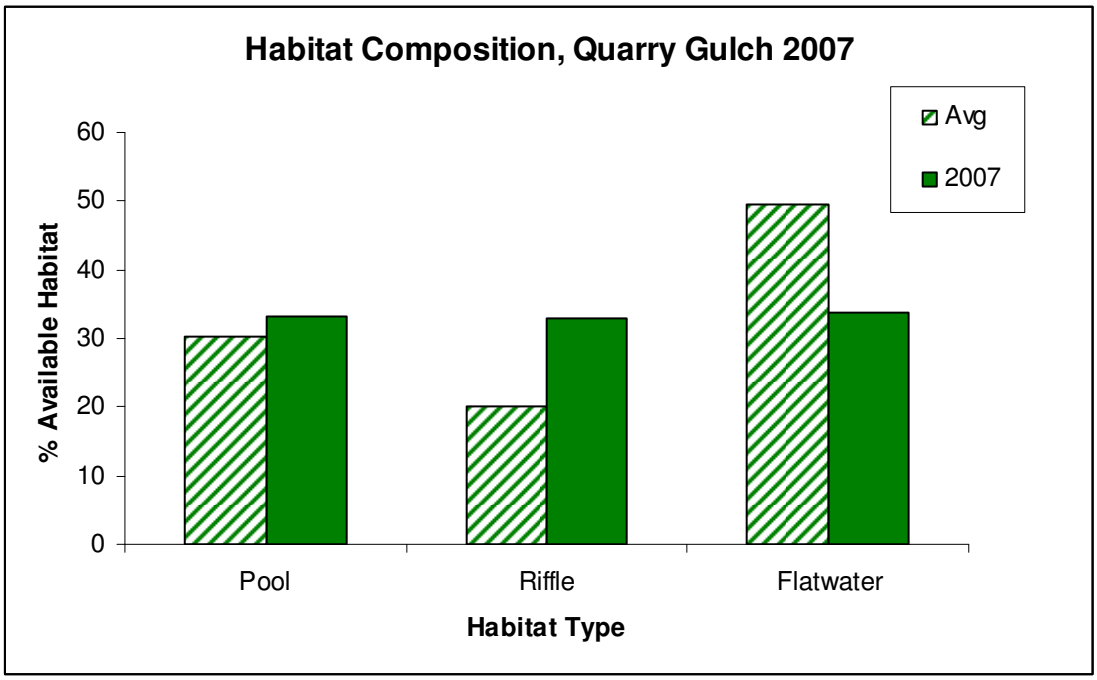


Figure B11. Comparison of historic (2005-2006) averages of percent available habitat and 2007 survey results.

Summer fish measurement information: As part of the summer monitoring program, a subsample of fish are weighed and measured within each sampled habitat unit. Histograms are presented for coho (Figure B12) and steelhead (Figure B14). Weight-length relationships are shown for coho (Figures B13) and steelhead (Figure B15). Historical relationships are shown for comparison across years.

Within the Quarry Gulch sample, 28 coho salmon (100% of the total catch) and nine steelhead trout (100% of the total catch) were weighed and measured in 2007. The size range for young of year coho was observed to be 49 to 76 mm, while the size range for steelhead trout was 45 to 134 mm.

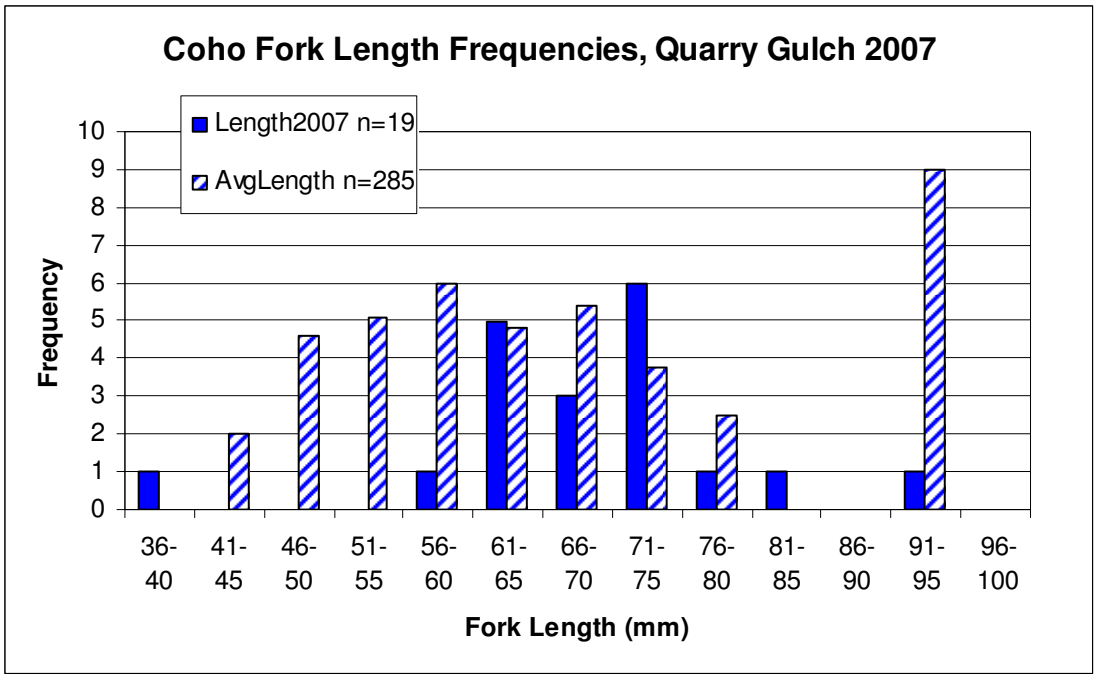


Figure B12. Coho histogram for fish measured in Quarry Gulch, 2007. Historic averages are added for comparison (2005-2006). Fork length is represented in 5 millimeter bins.

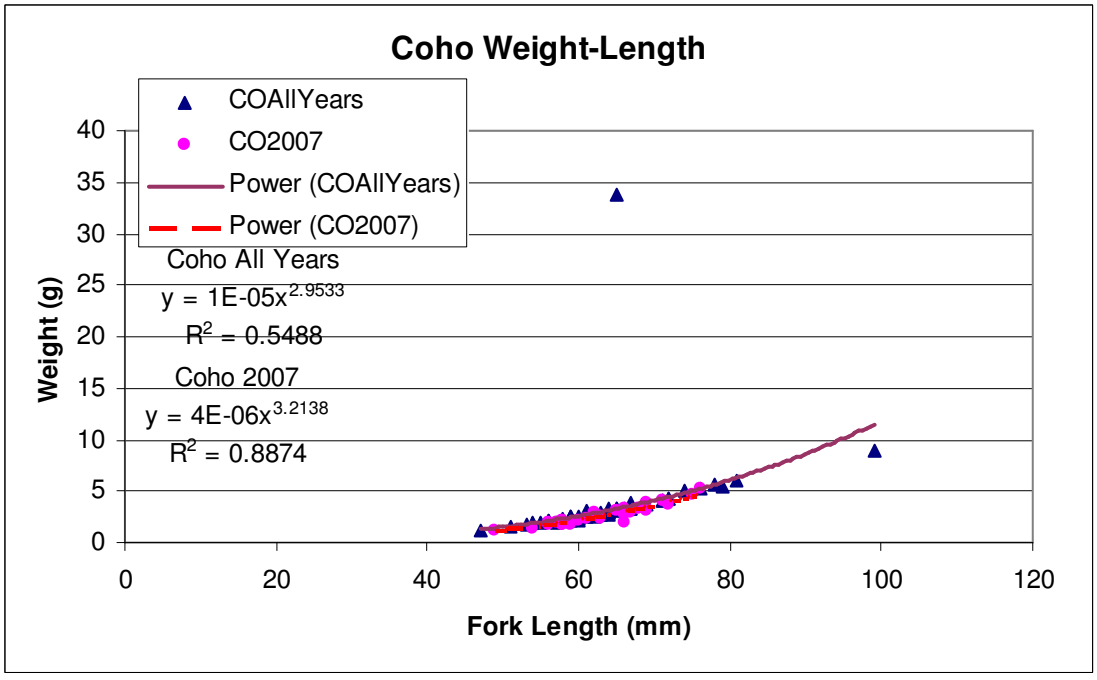


Figure B13. Coho weight-length relationship for fish measured in Quarry Gulch, 2007. Historical relationship added for comparison (2005-2006).

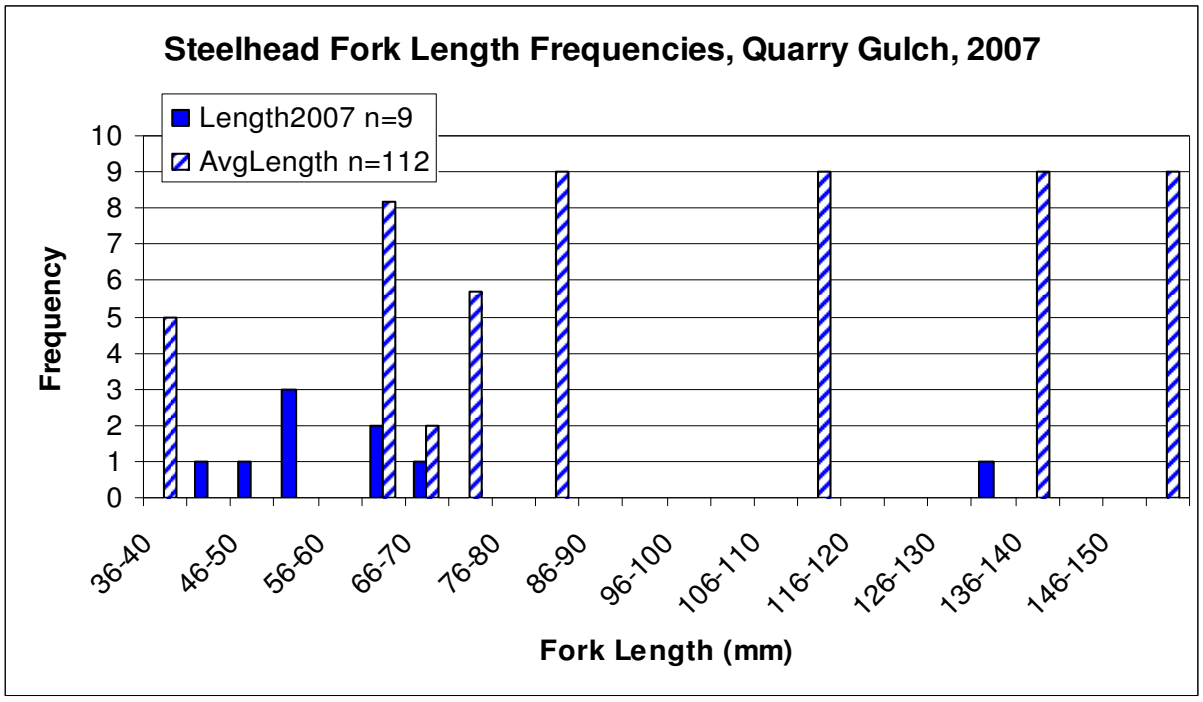


Figure B14. Steelhead histogram for fish measured in Quarry Gulch, 2007. Historical averages are added for comparison (2005-2006). Fork length is represented in 5 millimeter bins.

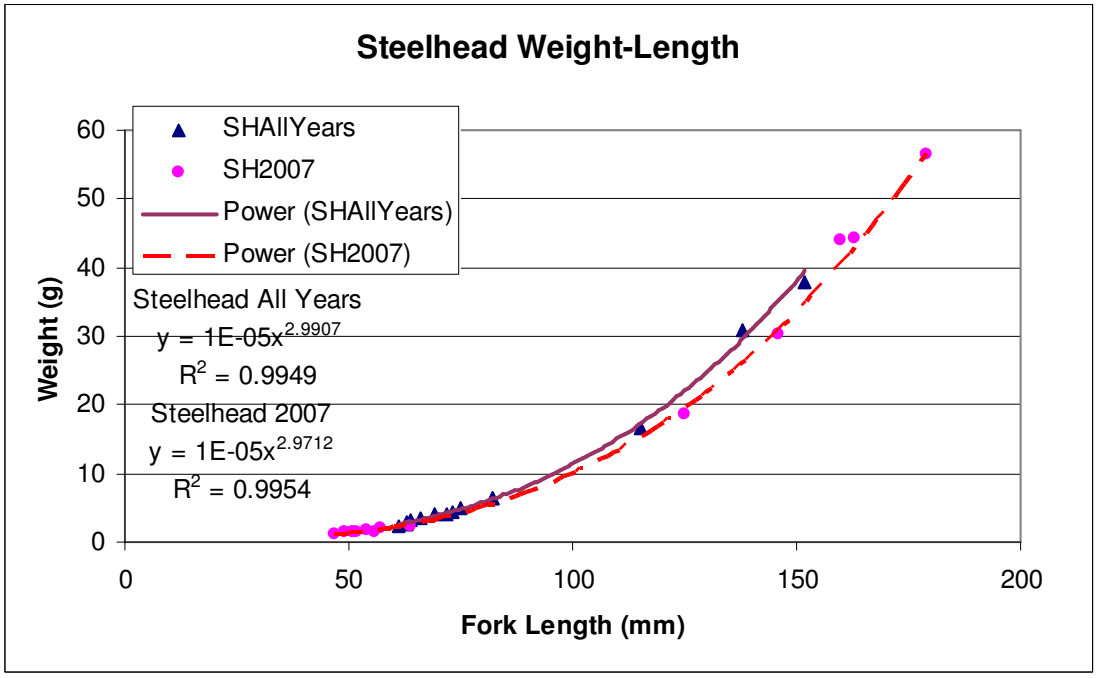


Figure B15. Steelhead weight-length relationship for fish measured in Quarry Gulch, 2007. Historical relationships are added for comparison (2005-2006).

Table B10 shows the coho length, weight, and K-factor for Quarry Gulch surveyed between 2005 and 2007. Tables B11 and B12 show the comparisons between steelhead young-of-year (YOY) and steelhead 1+ length, weight, and K-factors for Quarry Gulch surveyed between 2005 and 2007.

Table B10. Mean length, weight, K-factor, and standard deviation (SD) calculated for coho measured and weighed in Quarry Gulch, 2005-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2007	28	63.25	6.60	2.69	0.99	1.02	0.12
2006	15	65.87	10.45	5.46	8.01	1.88	2.88
2005	35	63.37	7.84	3.06	1.17	1.15	0.06

Table B11. Mean length, weight, K-factor, and standard deviation (SD) calculated for steelhead YOY measured and weighed in Quarry Gulch, 2005-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2007	8	56.13	8.11	1.82	0.88	0.96	0.11
2006	10	69.40	7.76	3.94	1.48	1.13	0.08
2005	1	64	N/A	3.14	N/A	1.20	N/A

Table B12. Mean length, weight, K-factor, and standard deviation (SD) calculated for steelhead 1+ measured and weighed in Quarry Gulch, 2005-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2007	1	134	N/A	23.23	N/A	0.97	N/A
2006	3	135	18.68	28.44	10.77	1.12	0.05
2005	1	75	N/A	5.07	N/A	1.20	N/A

B.3.2 Seine Counts

In 2007, juvenile salmonid surveys were conducted on 17% of the delineated pools with coho being observed in 100% of the total pools sampled. A total of 28 coho were counted in the four seined pools giving an average of seven coho per pool. Steelhead were observed in all of the pools sampled. A total of nine steelhead (both YOY and 1+) were counted in the four seined pools giving an average of 2.25 steelhead per pool (Table B13).

Table B13. Summary of total catch for GSS survey on Quarry Gulch, 2006-2007.

Year	Total Length Surveyed (km)	Total Habitat Units	Number of Pools					Raw Totals		
			Total	E-Fished	w/ coho	w/ SH YOY	w/ SH 1+	CO	SH YOY	SH 1+
2007	0.67	100	23	4	4	4	4	28	8	1
2006	0.6	93	22	5	3	3	1	22	10	3

B.3.3 Population Estimate

Due to the presence of red-legged frogs within the sample units, seine techniques were employed until depletion was obtained. From the data collected during the 2007 Quarry Gulch

equiprobable GSS survey, we were able to derive a population estimate, variance, and a 95% confidence interval for coho salmon. Results are shown in Table B14. In 2007, Quarry Gulch contributed an estimated 161 coho juveniles to the Olema Creek Watershed.

Table B14. Quarry Gulch population estimate and confidence interval (CI), 2007.

Year	Species	Population Estimate	Variance	95% CI
2007	CO	161*	2,177	±93

*Due to red-legged frog presence, pool units were seined until depletion.

B.4 Cheda Creek (Lagunitas Creek)

Cheda Creek is a contributor to the Lagunitas Creek watershed, and, along with Bear Valley Creek, can be used when comparing pre and post restoration conditions along a creek. In 2000, a large restoration project along the length of the creek below a large cattle crossing was completed. As such, it is is an example of a post-restoration stream.

The 2007 summer habitat survey of Cheda Creek was initiated at the confluence with the Lagunitas mainstem and ended above the cattle crossing for Cheda Ranch. The measured GSS survey length was 1.2 km. In previous years, this length has ranged from 1.7 km to 1.9 km. Through our electrofishing surveys, we captured juvenile coho salmon in all of the six e-fished pools including within an above the fish passage structure.

B.4.1 Habitat Survey

In 2007, a total of 155 habitat units were delineated within the GSS survey area with 34 pool units representing 22% of the total units. Six pools were selected and sampled representing an 18% subsample. At the time of the survey, Cheda Creek was disconnected to the Lagunitas mainstem by a 3.7 m dry section. Figure B16 shows a comparison of the historic averages of available habitat by survey, and the results of the 2007 survey.

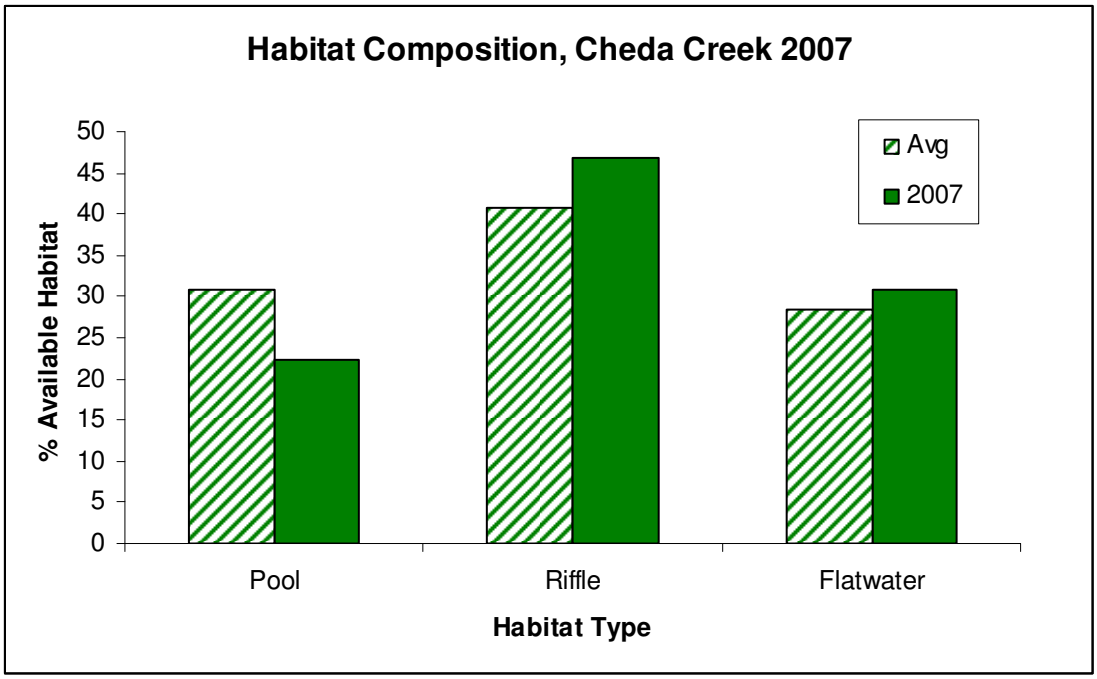


Figure B16. Comparison of historic average percentages of available habitat and 2007 survey results (2005-2006).

Summer fish measurement information: As part of the summer monitoring program, a subsample of fish are weighed and measured within each sampled habitat unit. Histograms are presented for coho (Figure B17) and steelhead (Figure B19). Weight-length relationships are shown for coho (Figures B18) and steelhead (Figure B20). Historic relationships are shown for comparison across the sample years.

Within the Cheda Creek sample, 75 coho salmon (67% of the total catch) and 99 steelhead trout (40% of the total catch) were weighed and measured. The size range for young of year coho was observed to be 36 to 81 mm, while the size range for steelhead trout was 39 to 207 mm.

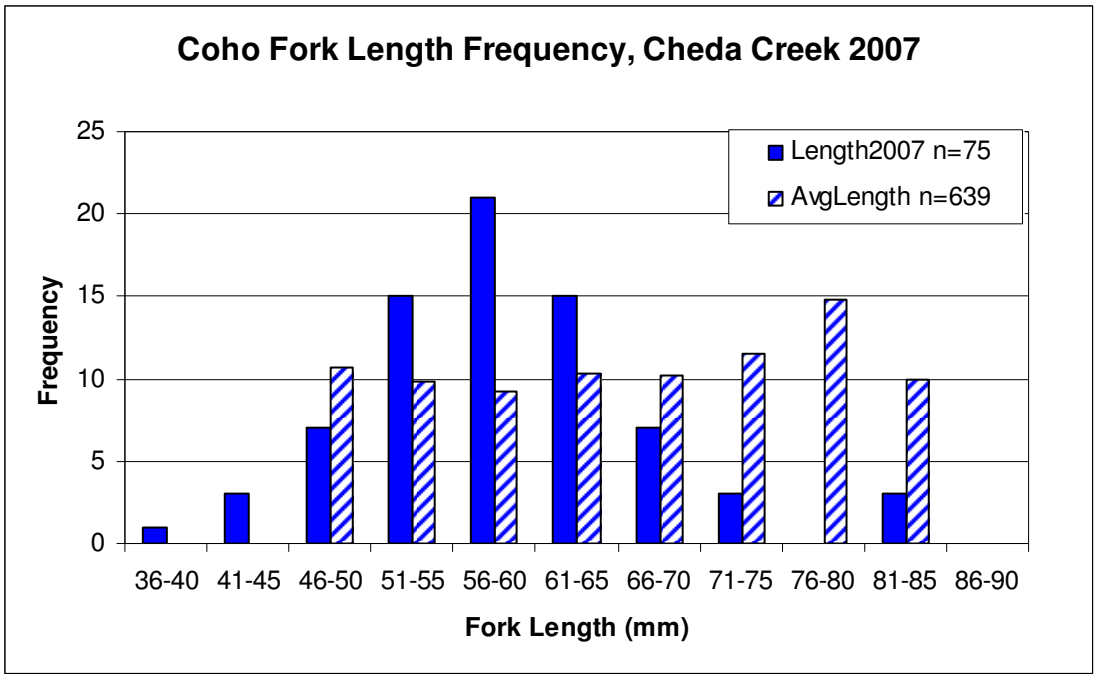


Figure B17. Coho histogram for fish measured in Cheda Creek, 2007. Historic averages (2005-2006) are shown for comparison. Fork length is represented in 5 millimeter bins.

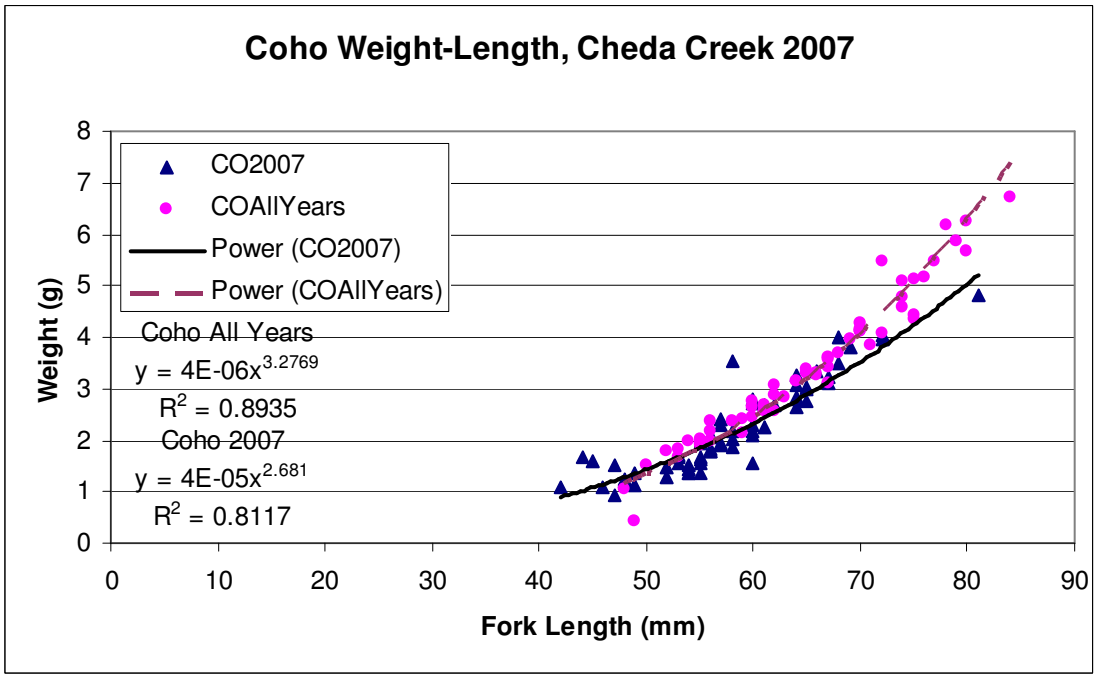


Figure B18. Coho weight-length relationship for fish measured in Cheda Creek, 2007. Historic relationships are shown for comparison.

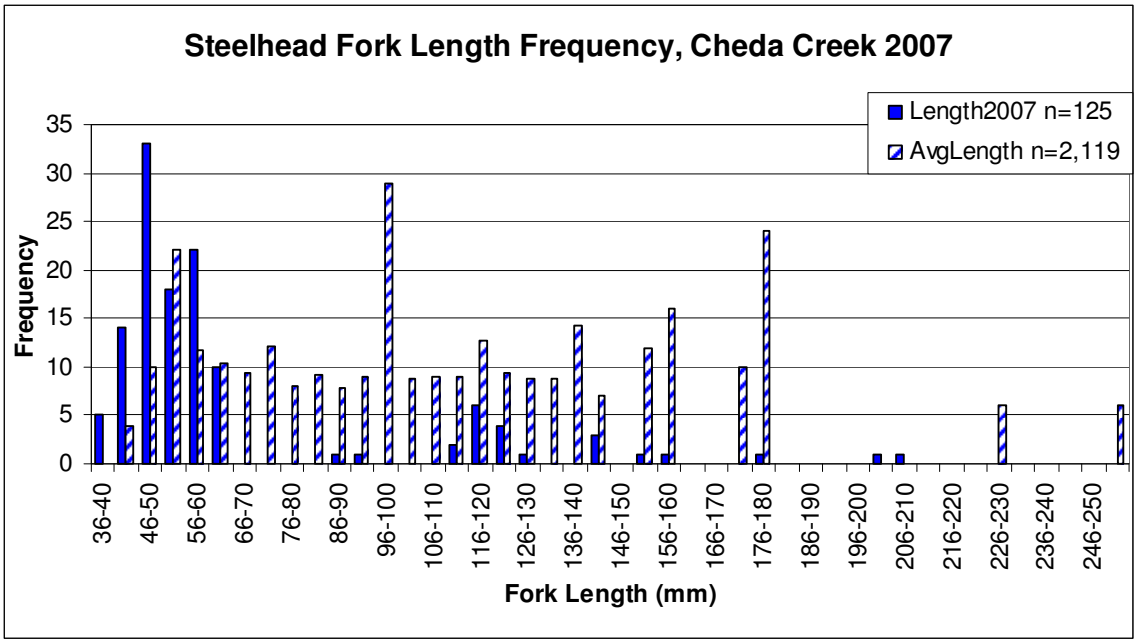


Figure B19. Steelhead histogram for fish measured in Cheda Creek, 2007. Historic averages are shown for comparison (2005-2006). Fork length is represented in 5 millimeter bins.

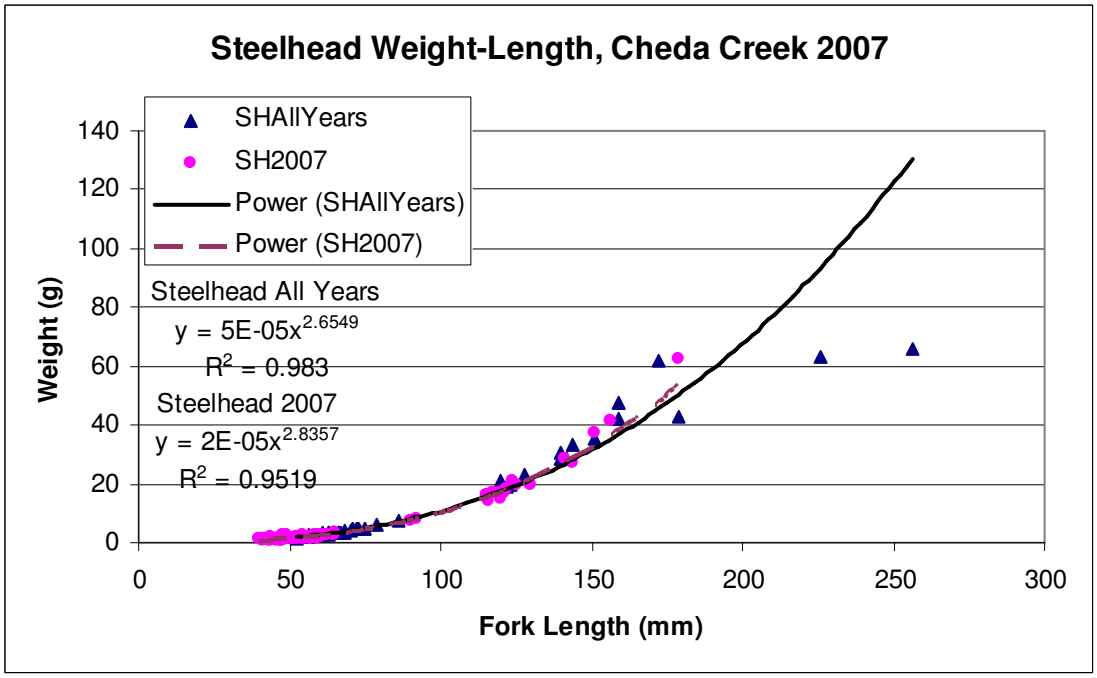


Figure B20. Steelhead weight-length relationship for fish measured in Cheda Creek, 2007. Historic relationships added for comparison (2005-2006).

Table B15 shows the coho length, weight, and K-factor for Cheda Creek sampled between 2005 and 2007. Tables B16 and B17 show the comparisons between steelhead young-of-year (YOY) and steelhead 1+ length, weight, and K-factors for Cheda Creek sampled between 2005 and 2007.

Table B15. Mean length, weight, K-factor, and standard deviation (SD) calculated for coho measured and weighed in Cheda Creek, 2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2007	64	57.86	7.46	2.23	0.88	1.11	0.21
2006	7	77.14	3.95	5.87	0.56	1.25	0.11
2005	53	62.72	7.93	2.99	1.13	1.15	0.13

Table B16. Mean length, weight, K-factor, and standard deviation (SD) calculated for steelhead YOY measured and weighed in Cheda Creek, 2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2007	79	52.32	6.26	1.71	0.61	1.18	0.35
2006	94	65.23	8.46	3.51	1.42	1.20	0.09
2005	46	67	9.90	3.76	1.54	1.18	0.12

Table B17. Mean length, weight, K-factor, and standard deviation (SD) calculated for steelhead 1+ measured and weighed in Cheda Creek, 2005-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2007	20	125.65	20.57	21.92	12.71	1.02	0.07
2006	21	150.10	34.84	33.63	14.90	1.01	0.21
2005	36	120.22	20.16	20.72	11.61	1.11	0.07

B.4.2 Electrofishing Counts

Electrofishing surveys were conducted on 18% of the delineated pools with coho being observed in 100% of the total pools sampled. A total of 112 coho were counted in the six e-fished pools giving an average of 18.7 coho per pool. Steelhead were observed in 100% of the total pools sampled. A total of 249 steelhead (both YOY and 1+) were counted in the six e-fished pools giving an average of 41.5 steelhead per pool (Table B18).

Table B18. Summary of total catch for GSS survey on Cheda Creek, 2007.

Year	Total Length Surveyed (km)	Total Habitat Units	Number of Pools					Raw Totals		
			Total	E-Fished	w/ coho	w/ SH YOY	w/ SH 1+	CO	SH YOY	SH 1+
2007	1.23	154	31	6	6	6	5	112	226	23
2006	1.8	219	63	9	3	9	7	8	121	29

B.4.3 Population Estimate

Estimates for population size and variance, in addition to, a 95% confidence interval were derived from the 2007 Cheda Creek equiprobable GSS survey. Results are shown in Table B19. In 2007, Cheda Creek contributed approximately 589 coho to the Lagunitas Creek watershed.

Table B19. Cheda Creek population estimates and confidence intervals (CI), 2007.

Species	Population Estimate	Variance	95% CI
CO	589	10,240	±202
SH YOY	1,333	74,576	±546
SH 1+	119	724	±54

B.5 Bear Valley Creek

Bear Valley Creek is a contributor to the larger Lagunitas Creek Watershed. While there have culvert replacements that have occurred along the length of Bear Valley Creek, no major restoration has occurred along the stream bed, and as such, can be considered a stream in the pre-restoration phase.

The 2007 summer habitat survey of Bear Valley Creek started at monument tag 6 and ended at the Meadow Trail walking bridge, monument tag 40. The measured GSS survey length was 3.4 km. In previous years, this length has ranged from 3.5 to 4.2 km.

One juvenile coho was captured 0.57 km from the Bear Valley Creek confluence with Lagunitas. This was the first coho observed in Bear Valley Creek since monitoring began in 2005. Combined with mild spring weather, moderate flows, and consistent access to the low reaches of Bear Valley Creek, we suspect that this one coho migrated up from the Lagunitas Creek mainstem.

B.5.1 Habitat Survey

In 2007, a total of 394 habitat units were delineated within the GSS survey area with 92 pool units representing 23% of the total units. Eighteen pools were selected and sampled representing a 20% subsample. One dry sections of streambed located approximately 2 km upstream from the confluence with Lagunitas Creek accounted for 307 meters of the total length surveyed. Figure B21 shows a comparison of the historic averages of available habitat by survey, and the results of the 2007 survey.

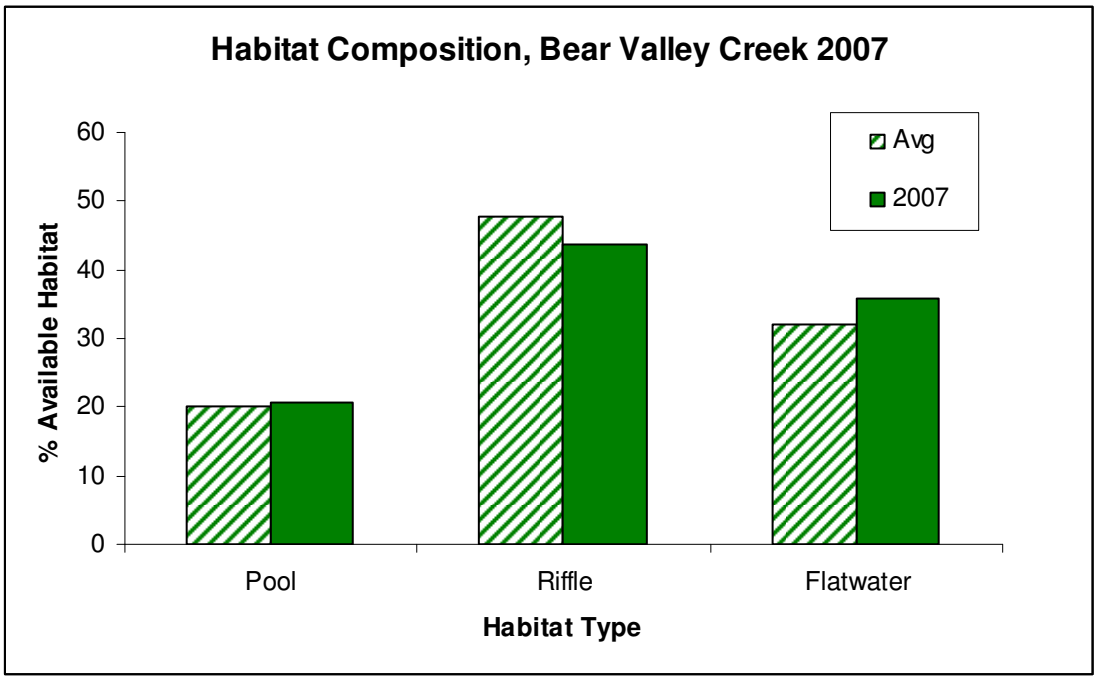


Figure B21. Comparison of historic (2005-2006) averages of percent available habitat and 2007 survey results.

B.5.2 Summer Fish Measurement Information

As part of the summer monitoring program, a subsample of fish are weighed and measured within each sampled habitat unit. A histogram is presented for steelhead (Figure B22). Weight-length relationships are shown for steelhead (Figure B23). Historical relationships are presented for comparison across years.

Within the Bear Valley Creek sample, one coho salmon (100% of the total catch) and 129 steelhead trout (88% of the total catch) were weighed and measured. The size of the one young of year coho was 97 mm, while the size range for steelhead trout was 32 to 187 mm.

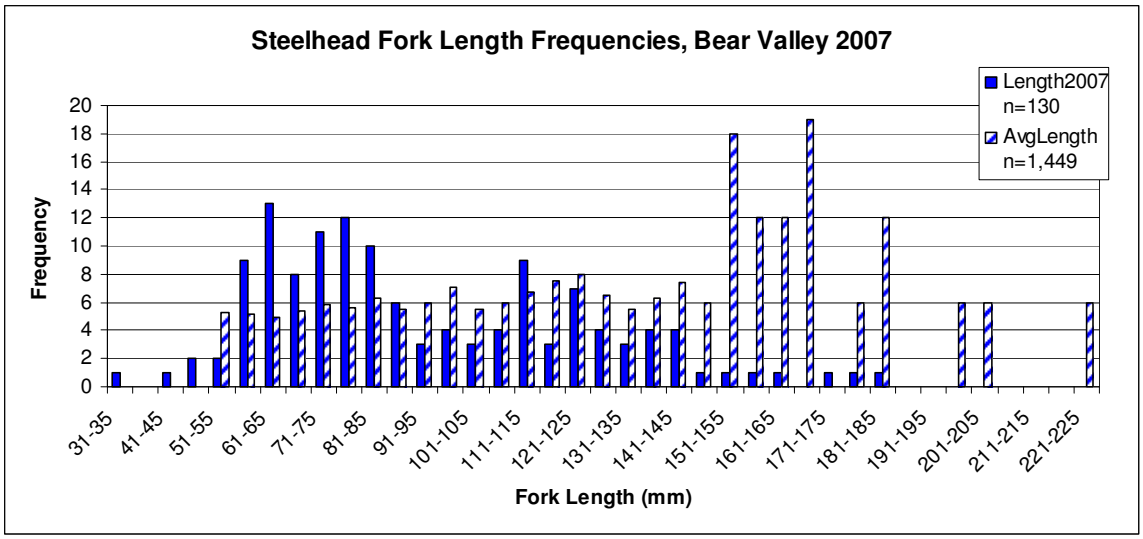


Figure B22. Steelhead histogram for fish measured in Bear Valley Creek, 2007. Historical averages are added for comparison (2005-2006). Fork length is represented in 5 millimeter bins.

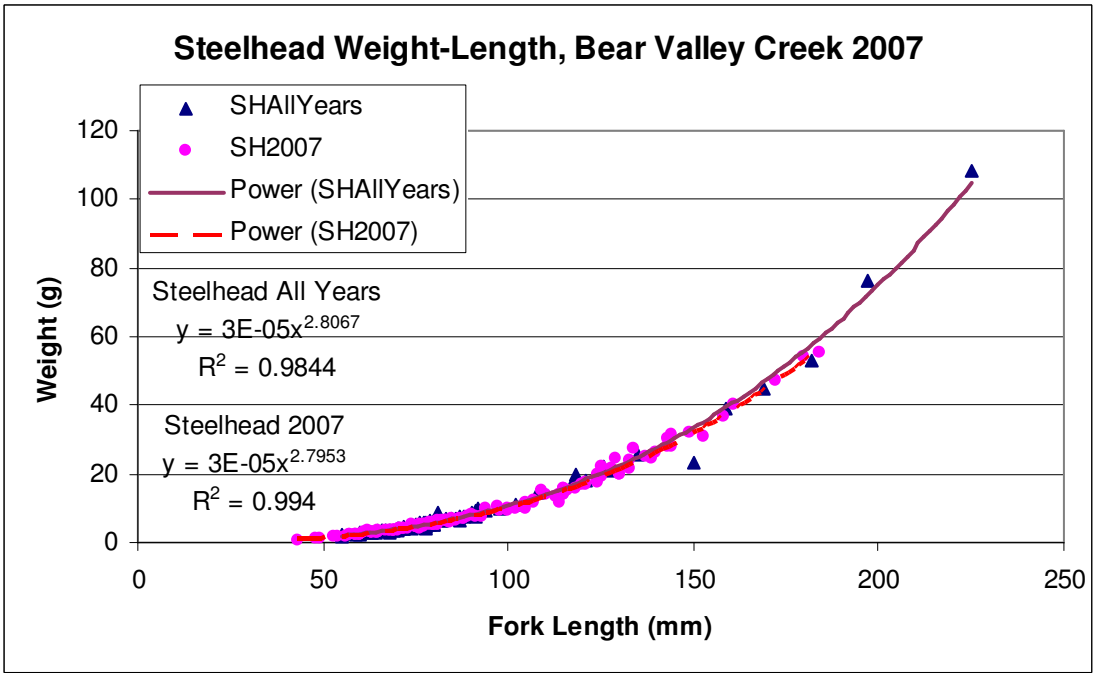


Figure B23. Steelhead weight-length relationship for fish measured in Bear Valley Creek, 2007. Historical relationships are shown for comparison (2005-2006).

Table B20 shows the coho length, weight, and K-factor for Bear Valley Creek. Tables B21 and B22 show the comparisons between steelhead young-of-year (YOY) and steelhead 1+ length, weight, and K-factors for Bear Valley Creek sampled between 2005 and 2007.

Table B20. Mean length, weight, K-factor, and standard deviation (SD) calculated for coho measured and weighed in Bear Valley Creek, 2007.

Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
1	97	N/A	9.08	N/A	0.99	N/A

Table B21. Mean length, weight, K-factor, and standard deviation (SD) calculated for steelhead YOY measured and weighed in Bear Valley Creek, 2005-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2007	74	70.84	10.80	3.98	1.67	1.06	0.07
2006	23	87.43	9.27	8.23	2.51	1.20	0.10
2005	169	76.34	10.86	5.31	2.57	1.12	0.14

Table B22. Mean length, weight, K-factor, and standard deviation (SD) calculated for steelhead 1+ measured and weighed in Bear Valley Creek, 2005-2007.

Year	Sample Size	Mean Length (mm)	Length SD	Mean Weight (g)	Weight SD	Mean K-Factor	K-Factor SD
2007	54	124.80	21.47	20.07	10.78	0.96	0.07
2006	17	143.76	21.89	33.61	16.31	1.07	0.15
2005	29	142.45	25.34	31.26	19.53	1.01	0.11

B.5.3 Electrofishing Counts

Electrofishing surveys were conducted on 20% of the delineated pools with coho being observed in one of the sampled pools. A total of one coho was counted in the 18 pools sampled, giving an average of 0.06 coho per pool. This represents the first time coho have been documented in Bear Valley Creek during monitoring efforts since 1996.

Steelhead were observed in 100% of the total pools sampled. A total of 147 steelhead (both YOY and 1+) were counted in the 18 pools e-fished giving an average of 8.2 steelhead per pool (Table B22).

Table B23. Summary of total catch for GSS survey on Bear Valley Creek, 2006-2007.

Year	Total Length Surveyed (km)	Total Habitat Units	Number of Pools					Raw Totals		
			Total	E-Fished	w/ coho	w/ SH YOY	w/ SH 1+	CO	SH YOY	SH 1+
2007	3.44	394	92	18	1	16	16	1	92	55
2006	1.6	176	47	19	0	19	12	0	194	36

B.5.4 Population Estimate

Estimates for population size and variance, in addition to, a 95% confidence interval were derived for steelhead from the 2007 Bear Valley equiprobable GSS survey. Results are shown in Table B24.

Table B24. Bear Valley population estimates and confidence intervals (CI), 2007.

Year	Species	Population Estimate	Variance	95% CI
2007	CO	N/A*	-	-
	SH YOY	470	11,339	±213
	SH 1+	302	2,630	±103

*One juvenile coho was captured in Bear Valley Creek for the first time since monitoring began in 2005.

Appendix C. Julian Week Table

Table C1. List of Julian weeks and their calendar equivalents non-leap year.

Julian week Number	Inclusive Dates	Julian week Number	Inclusive Dates
1	Jan 01 - Jan 07	27	Jul 02 - Jul 08
2	Jan 08 - Jan 14	28	Jul 09 - Jul15
3	Jan 15 - Jan 21	29	Jul 16 -Jul 22
4	Jan 22 - Jan 28	30	Jul 23 - Jul 29
5	Jan 29 - Feb 04	31	Jul 30 - Aug 05
6	Feb 05 - Feb 11	32	Aug 06 - Aug 12
7	Feb 12 - Feb 18	33	Aug 13 - Aug 19
8	Feb 19 - Feb 25	34	Aug 20 - Aug 26
9	Feb 26 - Mar 04	35	Aug 27 - Sep 02
10	Mar 05 - Mar 11	36	Sep 03 - Sep 09
11	Mar 12 - Mar 18	37	Sep 10 - Sep 16
12	Mar 19 -Mar 25	38	Sep 17 - Sep 23
13	Mar 26 - Apr 01	39	Sep 24 - Sep 30
14	Apr 02 - Apr 08	40	Oct 01 - Oct 07
15	Apr 09 - Apr 15	41	Oct 08 - Oct 14
16	Apr 16 - Apr 22	42	Oct 15 - Oct 21
17	Apr 23 - Apr 29	43	Oct 22 - Oct 28
18	Apr 30 - May 06	44	Oct 29 - Nov 04
19	May 07 - May 13	45	Nov 05 - Nov 11
20	May 14 - May 20	46	Nov 12 - Nov 18
21	May 21 - May 27	47	Nov 19 - Nov 25
22	May 28 - Jun 03	48	Nov 26 - Dec 02
23	Jun 04 - Jun 10	49	Dec 03 - Dec 09
24	Jun 11 - Jun 17	50	Dec 10 - Dec 16
25	Jun 18 - Jun 24	51	Dec 17 - Dec 23
26	Jun 25 - Jul 01	52	Dec 24 - Dec 31

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 641/100681, November 2009

National Park Service
U.S. Department of the Interior

Natural Resource Program Center
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov